THE GLASS INDUSTRY
THE JOURNAL OF GLASS MANUFACTURING
VOLUME 41 NUMBER 10 OCTOBER 1960

Glass Division Program

BEDFORD SPRINGS: October 12-14

• THE GLASS DIVISION of the American Ceramic Society will hold its fall meeting at Bedford Springs, Pa., October 12-14. Guy E. Rindone, chairman, and Clarence L. Babcock, program chairman, have arranged a schedule including a methods workshop technical sessions, and entertainment, that is designed to occupy the participants completely during the three day event. Mrs. Charles E. Gum is general chairman of the Ladies Entertainment Committee.

Banquet

The banquet address "Color and Color Mixtures—Old and New," will be given by Dr. Isay Balinkin, Professor of experimental physics, University of Cincinnati. During the banquet the Frank Forrest and S. B. Meyer, Jr., awards will be presented for the two most credible papers on glass technology published during the preceding year. James P. Poole and Robert H. Dalton, scrutineers for this year's awards, have nominated the following men: Frank Forrest Award, C. L. McKinnis, Owens-Corning Fiberglas Corp., Glass Res. Lab., Newark, O., and J.W. Sutton, Boeing Airplane Co., Pilotless Aircraft Div., Seattle, Wash., for their paper, "The Glass Making Process I.—A Theory of the Nature of Silicate Melts and of Their Interaction with Silica," J. Am. Cer. Soc. *42*, 194 (1959). S. B. Meyer Jr., Award, Robert Gardon, Pittsburgh Plate Glass Co., Glass Research Center, Box 11472, Pittsburgh 38, Pa., for his paper, "Calculation of Temperature Distribution in Glass Undergoing Heat Treatment," J. Am. Cer. Soc. *41*, 200 (1958).

Technical Sessions and Workshop

The technical sessions will run in three half-day segments and the workshop "Methods of Studying Crystallization Phenomena in Glass," will be held on Thursday afternoon. The Glass Division's business meeting is scheduled for 11 a.m. on Thursday and the ASTM Committee C-14 will have a luncheon meeting on the same day. Officers of the Glass Division are: Trustee, August C. Siefert, Owens-Corning Fiberglas Corp.; Chairman, Guy E. Rindone, Pennsylvania State University; Vice Chairman, J. R. Hensler, Bausch & Lomb Optical Co.; Secretary, Fay V. Tooley, University of Illinois.

Papers

THURSDAY, OCTOBER 13

9:00 A.M.

Session Chairman: GUY E. RINDONE
Pennsylvania State University, University Park, Pa.

1-G-60F. Crystals in Glass and Their Significant Effect on Physical Properties
Francis C. Lin, Westinghouse Electric Corp., Ceramics Section, Pittsburgh 8, Pa.

2-G-60F. The Thermal History of Glass I. The Density Variations of Glass During Crystallization and Heat Treatment
Bernard L. Steierman and *Tryggve Baak,* Fundamental Research Sec., General Research Div., Owens-Illinois Technical Center, Toledo, Ohio

3-G-60F. Diffusion of Oxygen from Contracting Bubbles in Molten Glass
R H. Doremus, General Electric Laboratory, Schenectady, N. Y.

4-G-60F. Ion Exchange Between Soda-Lime Glass and Molten Lithium and Silver Salts
C. M. Hollabavgh and *F. M. Ernsberger,* Pittsburgh Plate Glass Co., Glass Research Center, Pittsburgh 38, Pa.

11 A.M. Business Meeting of the Glass Division
Chairman Guy E. Rindone, presiding

THURSDAY, OCTOBER 13

2:00 P.M.

Session Chairman: H. R. SWIFT
Libbey-Owens-Ford Glass Co., Toledo, Ohio

Workshop:

Method of Studying Crystallization Phenomena in Glass

Method for Studying the Devitrification Process in Glass
R. J. Jaccodine, Bell Telephone Laboratories, Allentown, Pa.

A Hot-Stage Petrographic Microscope for Glass Research
T. W. Brock, Owens-Illinois Technical Center, Toledo, Ohio

Determination of Precent Crystallinity of Partially Devitrified Glass by X-ray Diffraction
Stanley M. Ohlberg and *Donald W. Strickler*, Pittsburgh Plate Glass Co., Pittsburgh, Pa.

Methods Used for Studying Glass Devitrification Phenomena at the Bureau of Standards
Given W. Cleek, National Bureau of Standards, Washington, D. C.

Liquidus Measurement Methods Used for Control Purposes
Leon R. Schloizhauer, Corning Glass Works, Corning, N. Y.

Devitrification Studies on Borosilicate Glasses
C. L. McKinnis, Owens-Corning Fiberglas Corp., Granville, Ohio

FRIDAY, OCTOBER 14

9:00 A.M.

Session Chairman: CLARENCE L. BABCOCK
Owens-Illinois Technical Center, Toledo, Ohio

5-G-60F. Kinetics of Reactions Occurring in the Glass Preparation Process
Elwin L. Johnson, Materials Research Dept., Central Research Laboratories, Texas Instruments Inc., Dallas, Texas, and *F. V. Tooley*, Department of Ceramic Engr., University of Illinois, Urbana, Ill.

6-G-60F. Correlation of Strength of Glass with Fracture Flaws of Measured Size
Errol B. Shand, Technical Consultant, 155 Reynolds Ave., Corning, N. Y.

7-G-60F. A New Method for the Experimental Determination of the Limiting Molecular Strength of Glass
F. M. Ernsberger and *D. E. Braithwaite*, Glass Research Center, Pittsburgh Plate Co., Pittsburgh 38, Pa.

8-G-60F. Some Glasses for the Transmission of Ultraviolet Radiation
Francis W. Glaze, Jack M. Florence, Jerome S. Osmalov, Douglas H. Blackburn, Herman F. Shermer, and *Mason H. Black*, National Bureau of Standards, Washington 25, D. C.

9-G-60F. Solutions for Unsteady State Heat Flow in Situations Representative of Some Types of Glass Molding
A. R. Cooper, Jr., Ceramics Div., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

10-G-60F. Fluorine Release from Glasses
Louis Spanoudis and *Josef Francl*, Kimble Division of Owens-Illinois, Owens-illinois Technical Center, Toledo 1, Ohio

11-G-60F. Preparation of Oxide Glass Films by Reactive Sputtering
W. Robert Sinclair and *F. G. Peters*, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

FRIDAY, OCTOBER 14,

2:00 P.M.

Session Chairman: HAROLD E. SIMPSON
State University of New York College of Ceramics, Alfred, N. Y.

12-G-60F. The Iron Equilibria in Glasses: The Effect of Platinum on the Fe^{2+}/Fe^{3+} Equilibrium
Emery J. Hornyak and *Tryggve Baak*, Fundamental Research Sec., General Research Div., Owens-Illinois Technical Center, Toledo, Ohio

13-G-60F. The Constitution of Mixed Alkali Phosphate Glasses: II. The Constitution of Variable Lithium Constant Sodium-Potassium Phosphate Glasses
A. E. R. Westman and *M. Krishna Murthy*, Ontario Research Foundation, Toronto 5, Ontario, Canada

14-G-60F. The Influence of Platinum Nucleation on the Constitution and Structure of Sodium Phosphate Glasses
M. Krishna Murthy, Department of Chemistry, Ontario Research Foundation, Toronto 5, Ontario, Canada

15-G-60F. Gamma Irradiation Studies of Some Borate Glasses*
Adli Bishay, Resident Research Associate, Remote Control Engineering Div., Argonne National Laboratory, Argonne, Illinois. On leave of absence from The American University at Cairo, Egypt.
*Work performed under the auspices of the U. S. Atomic Energy Commission.

16-G-60F. The Coordination of Boron in B_2O_3 Glass
Scott Anderson, The Anderson Physical Laboratory, Champaign, Ill.

The Conditions of Glass Formation Among Simple Compounds* IN FOUR PARTS

by *W. A. Weyl and E. C. Marboe,* College of Mineral Industries, The Pennsylvania State University, University Park, Pennsylvania. U. S. A.

Part II

Kinetic Approach to Nucleation and Glass Formation

TABLE OF CONTENTS

I. Introduction

The Importance of Rate Phenomena in Glass Technology

II. Some Fallacies Concerning Rate Phenomena

III. Factors Controlling Nucleation and Glass Formation

1. *The Rate of Cooling*
2. *The Liquidus Temperature*
3. *The Activation Energy of Nucleation*
4. *Parameters Determining the Activation Energy of Viscous Flow and of Nucleation*
   a. *The Chemical Binding Forces*
   b. *Viscosity Versus Nucleation and Crystallization*
5. *Atomic Structure and Glass Formation*
6. *Effect of Minor Additions on Nucleation*
   a. *Positive Nucleation Catalysts*
   b. *Negative Nucleation Catalysts*

IV. Conclusions and Summary

I. INTRODUCTION

The Importance of Rate Phenomena in Glass Technology

● THE POSSIBILITY AND THE ECONOMY of manufacturing soda lime silicate glasses on a large scale and the fact that they are useful under atmospheric conditions are the results of several favorable rate phenomena. On the basis of our present knowledge of the physical chemistry of silicates this possibility could not have been predicted. Firstly, soda lime silicates are not stable in the glassy state, but on cooling these melts should change into crystals such as tridymite (SiO_2), wollastonite ($CaO{\cdot}SiO_2$), and devitrite ($Na_2O{\cdot}3CaO{\cdot}6SiO_2$). Secondly, one might arrive at the conclusion that the large-scale manufacture of such a glass is impractical because the melt reacts with all refractory materials which are available for making containers or tank blocks. The phase diagrams reveal that no refractory oxide is in equilibrium with a melt of the composition of technical glasses. Hence, the manufacture of glass is possible only because of the relatively slow rates at which the molten silicates change into the more stable crystals and the rates at which the refractory materials react with the glass. The rate of the reaction of some refractory materials with a soda lime silicate is not negligible but it does not constitute a serious obstacle which impairs the economy of glass manufacture.

Glass technologists are interested in developing glasses which have a low rate of devitrification and in obtaining refractories which react only slowly with the molten glass. Reluctance of nucleation and crystallization of molten silicates on cooling and slow rates of refractory corrosion by the glass melt are the fundamental rate phenomena which make the manufacture of silicate glasses possible.

In addition to these two fundamental rate processes other rate phenomena are important to the glass technologist. For example, the rate of melting of the glass batch, the rate of removing gas bubbles from the melt, and the rate of diffusion processes which are essential in removing inhomogeneities (cords). These rate processes are important for the economy of glass melting.

After the glass has been melted and shaped its usefulness depends upon another favorable rate process; namely, its extremely slow rate of hydration and hydrolysis. The beautiful iridescence of ancient glasses tells us of its slow gradual hydration which leads to a film of weathered glass. Over a period of several hundred years the surface layer became hydrated, carbonated and selectively leached out by the water in combination with constituents from the atmosphere and the soil. A soda lime silicate glass is not only metastable with respect to the stable crystalline phases but also with respect to its reaction products with the atmosphere. The fact that window panes still exist which have survived the rains of centuries reveals that the process of hydrolysis is extremely slow. The same glasses in the form of fibers or fine powders exposed to the same atmospheric conditions would have disintegrated within short times.

Summarizing we may state that the manufacture and

*Mineral Industries Contribution No. 59-95

the use of soda lime silicate glasses is possible only because of favorable rate phenomena: The reluctance of some silicate melts to nucleate and to crystallize on cooling, the relatively slow rate of reaction of the molten glass with the refractory material, and finally, the extremely slow rate of hydration and hydrolysis of the finished glass.

In spite of this overwhelming importance of rate phenomena the glass technologist finds little information on this subject in the glass literature. There are several reasons for this shortcoming. Physical chemistry as a whole cannot deal with rate phenomena as well as with equilibria. There is no better way to characterize this situation than to quote from E. A. Moelwyn-Hughes[1] (1947), a scientist who devoted a lifetime to the exploration of rate phenomena:

"The inversion of sucrose is a classical reaction in several respects. It was the first chemical reaction which was timed and which was used for studying the relation between temperature and the rate of reaction. This reaction has attracted the attention of hundreds of investigators and over one thousand publications dealing with its kinetics have appeared since the days of Wilhelmy (1850). That we are still very far from understanding its mechanism is an illuminating comment on the difficulties attending the problem in general."

Considering the present status of rate phenomena in a simple homogeneous system such as a solution of sugar in water, it cannot surprise the glass technologist that he finds very little about this subject in his textbooks. The scientific basis of glass technology has been the phase diagram. A phase diagram is an expression of the equilibria in a system and of the way an equilibrium is affected by changes in temperature and composition. There is scarcely a textbook on glass which would not refer to the ternary system Na_2O-CaO-SiO_2 as worked out by G. W. Morey and N. L. Bowen. This diagram is the basis for the high temperature chemistry of the most important group of technical glasses: the soda lime silicate glasses. The young glass technologist is taught what this diagram means and how it is used. The same applies to other technologies which are based on high temperature physical chemistry, e.g., the manufacture of alloys, porcelain, enamel, etc. By far the largest part of our present knowledge of the high temperature chemistry of metals and oxides refers to equilibria and is vested in phase diagrams. Heterogeneous equilibria, in particular the conditions which determine the coexistence of liquid and solid phases in simple silicate systems as a function of the temperature, are well understood. These relations are based on thermodynamics.

The reasons why certain oxides can combine with silica and form one or more compounds, whereas others cannot, are also well understood, at least in a semiquantitative way, due to the work of A. Dietzel[2] which is based on crystal chemical concepts.

Going from equilibria to rate phenomena, however, leads us into fields where no such reliable tools as thermodynamics and crystal chemistry are available. Because of the tremendous importance of rate phenomena, scientists tried to correlate reaction rates with parameters such as the geometry of the crystal and with thermodynamic quantities such as dissociation energies and free energy changes. Much of this effort led to fallacies.

II. Some Fallacies Concerning Rate Phenomena

Our theoretical treatments of the viscosity of glasses[3], the hardness of simple crystals[4], their melting points[5], and the chemical reactions which occur during the corrosion of glass by acids[6], was based on K. Fajans' concepts of the mutual polarization of ions[7]. The greater the mutual polarization of the ions the greater becomes the lattice energy of an ionic crystal. The lattice energy of AgCl is greater than that of NaCl, but there is no simple relation between the degree of polarization as expressed in the lattice energy and rate phenomena. AgCl is soft and ductile, but NaCl is hard and brittle[8]. The bond energy depends upon whether one describes the bond as existing between neutral atoms or ions. As far as the Na-Cl bond strength is concerned one can calculate it from the lattice energy, i.e., the energy which is necessary in order to change 1 mole of NaCl into free gaseous Na and Cl^- ions. Dividing this energy by the number of NaCl bonds which exist in a crystal containing 1 mole NaCl gives us the bond strength. In an earlier paper[9] we proved that this value bears no relation to the energy which is required for breaking a NaCl crystal under tension. Even if it were possible to neglect the existing flaws, the crystal would be much weaker than one would expect from calculations based upon the number of bonds which have to be broken. The same applies to the use of bond strength for explaining viscosity. There is no simple and obvious relation between the energy necessary to bring about viscous flow in vitreous silica and the energy of the Si-O bonds because the mechanism of breaking a NaCl crystal or the mechanism of viscous flow of B_2O_3 and SiO_2 has nothing in common with the mechanism which is used for obtaining the numerical values of lattice energies and bond strength.

We find this fallacy of connecting viscosity with bond strength in papers where the author bases the bond strength on the electrical interaction between charged particles, i.e., cations and anions, as well as in those papers which are based on thermochemical data which give the energy which is required for dissociating a glass into electrically neutral atoms.

The concept that the bond strength between atoms is a decisive factor in determining the viscosity of a glass is based on the statistical-mechanical approach to rate phenomena. The atoms are treated as oscillators which are in permanent thermal vibration and, depending upon the amplitude of their vibrations and the frequencies (approximately 10^{13}/second), the bonds between two atoms are pictured as being broken constantly but capable of reforming at the same rate. As long as the rate of breakage of bonds is the same as that of their reformation no change occurs in the system.

According to this approach which is applied to chemical reactions as well as to diffusion and flow processes, each individual bond has a finite probability of being broken. This probability depends upon its strength Q and upon the energy of the vibration which increases with the absolute temperature T. The probability of breaking a bond is treated as being proportional to the expression $e^{-Q/kT}$ in which k is the Boltzmann constant. On this basis one assumes that the activation energy of a rate process is related to the chemical binding force Q.

Even within simple molecules, however, the energy of a bond between two atoms depends upon the rest of the molecule. In spite of all the advances which have been made in quantum mechanics, the concept that a mechanism exists which holds together two atoms with a certain force (the bond strength) is still deeply rooted in the minds of some physical chemists. In spite of overwhelming evidence against such a simple picture, some scientists continue to think in terms of "breaking of existing bonds" and "forming of new bonds" as the basic mechanism of chemical reactions and of viscous flow.

The energy of the C-C bond (80 kcal/mole) is less than that of the C-H bond (98 kcal/mole). Nevertheless, the interaction between ethane CH_3-CH_3 with deuterium gas, D_2, reveals that the C-H bond can be "broken" at a lower temperature than the C-C bond. Deuteroethane CH_2D-CH_3 forms at a lower temperature than that which is required for the formation of deuteromethane CH_3D.

The energy of the Si-Cl bond (87 kcal/mole) is greater than that of the C-Cl bond (78 kcal/mole). These bond energies stand in striking contrast to the reactivities of CCl_4 and $SiCl_4$ with water. CCl_4 is relatively inert to hydrolysis at ordinary temperature but $SiCl_4$ reacts with explosive violence.

These two examples show that the bond energies fail to account for the rates of even very simple chemical reactions and one cannot expect, therefore, that they can explain viscous flow or the kinetics of nucleation within the much more complex condensed state.

J. D. MacKenzie[10] (1956) calculated the energy of the B-O bond to ~ 100 kcal/mole. This value is very much the same as the energy of the Si-O bond (106 kcal/mole). The following sentences are quoted as examples for the failure of the mechanistic picture which is used for linking the bond strength to the flow behavior of B_2O_3 and SiO_2 glasses[10]:

"Viscous flow can, therefore, occur only by the rupture of B-O bonds, the most probable unit of flow being B_2O_3. However, the energy of activation for viscous flow for SiO_2 is about 130 kcal, almost four times greater than that for B_2O_3.

Thus for flow to occur, energy approximating to half of four B-O bonds is involved. As the same number of Si-O bonds must be broken when viscous flow takes place in SiO_2 it would appear that the energy of the Si-O bond is much greater than that of the B-O bond."

Comparing B_2O_3 and SiO_2 on the basis of electronegativity does not reveal major differences in the type of the bond. Using the boron-oxygen and the silicon-oxygen bond energies as a parameter one finds that the two are nearly identical. However, K. Fajans and S. W. Barber[11] pointed out that the viscosities of the two melts at 1260°C differ by nearly twelve orders of magnitude. The extrapolated viscosity ($\log \eta$) of B_2O_3 at 1260° is 1.4 and that of silica at the same temperature is 13.0.

Modern theoretical physics has abandoned the description of matter as consisting of atoms which have constant properties. The modern quantum mechanical treatment describes matter as consisting of the positive nuclei of the elements and a certain electron density distribution between the nuclei. It has been found necessary to speak of the probability of finding a certain electron density between two nuclei. As long as one deals with phenomena in which the nuclei of the system remain in their original positions and are subjected only to thermal vibrations, one can describe the event by assuming that the average electron density distribution among all nuclei remains constant over times which are long as compared with thermal vibrations. For the interpretation of these phenomena, the authors found that the ionic concept which considers the mutual deformation of ions represents the most useful description.

These conditions, however, do not apply to phenomena such as viscous flow in which the nuclei are moved from their equilibrium positions over distances which are larger than those for which Hook's law is valid. We must realize that the viscous flow of fused B_2O_3 and of SiO_2 involves a motion of the nuclei or boron, silicon, and oxygen which must be accompanied by major changes in the electron density distribution within the system.

During viscous flow no bonds are broken, therefore no new bonds have to be formed: the nuclei move through positions which are so far from their equilibrium positions that any description of the system which applies to its equilibrium state loses its usefulness.

A more widespread use of the dynamic models built by Dietzel and Deeg[12] would help to overcome the mechanistic description of reactions. In these models the electrical forces between ions are replaced by equivalent magnetic forces and not by mechanical devices such as wires. Those who study these dynamic models would never think of describing crystallization or a flow process as involving breakage of magnetic forces or bending of existing bonds.

Unfortunately the concept of breaking bonds is not the only fallacious concept which is used in the interpretation of rate phenomena. Another fallacy which affects our problem of glass formation involves the assumption that there is a simple relation between the energy difference, glass versus the corresponding crystal, and the rate of nucleation or crystallization.

The stability of a system is given by its free energy. A system which does not occupy its lowest energy level is instable or metastable. Metastable systems can remain unchanged indefinitely if no reaction path exists which enables the system to reach a lower energy level. One

can describe a metastable system as a high plateau surrounded by mountains. A lake located on such a plateau represents a potential source of energy for the surrounding low country provided one can find a path for the water to reach the lowlands. The energy which is available and which can be utilized for generating electricity is proportional to the amount of water in the lake and to the difference in altitude between the lake and the lowlands. This is as far as the comparison goes which one can draw between the high energy state of a system and its equilibrium state, and the difference in free energy between the two.

Of course scientists would like to go beyond this step and speculate on the rate of the reaction which will take place once a reaction path has been found. In our picture a possible path for the water would be a tunnel cut through the mountain so that the water in the lake could be brought down via a pipe. Under these conditions, one factor controlling the rate of flow, i.e., the amount of water which runs through the pipe in unit time, would be the difference in altitude between the two levels. No such relation, however, exists for the rate of a chemical reaction. The fallacy that $\triangle F$, the difference in the free energies of the two systems, determines the rate at which the unstable system changes into the stable one is deeply rooted. When Zachariasen[13] derived his rules concerning glass formation he based his assumption on the fallacy that the energy difference between a random structure (glass) and a periodic structure (crystal) ought to be small in order to have a low rate of nucleation which in turn enables a molten substance to solidify as a glass.

G. W. Morey[14] pointed out that the experimental data which are available do not support this assumption and he gives examples which contradict the reasoning of Zachariasen. Our criticism goes beyond this inconsistency between experimental facts and theory. We emphasize that there is no scientific basis on which one should expect a relationship to exist between glass formation or slow rate of nucleation on one hand and the energy difference between the supercooled liquid and the crystal on the other.

A calculation of the energy levels of the systems CCl_4-H_2O and $SiCl_4$-H_2O and those of the respective products of hydrolysis, i.e., CO_2-HCl and SiO_2-HCl, reveals that both chlorides in contact with water are unstable and that both systems can lower their free energies by undergoing hydrolysis. The values of the free energy changes are very different: the one for the hydrolysis of CCl_4 is approximately twice that for the hydrolysis of $SiCl_4$. In spite of this fact the system $SiCl_4$-H_2O reacts violently, whereas CCl_4 does not hydrolyze at room temperature at a noticeable rate. Earlier the rate of hydrolysis of these chlorides was used for demonstrating that the rates of hydrolysis are not related to the bond strength.

Glass formation is the result of a very low rate of nucleation of the supercooled liquid. Here we encounter another fallacy which can be found frequently, namely, the assumption that the mobility of particles requires the absence of strong binding forces. Obviously if an object is tied to its environment by weak forces it can be moved by a weak mechanical force. However, the fact that an object can be moved easily in one direction or the other does not mean that it is held by weak forces only. A steel ball which is too heavy to be lifted can be rolled easily on a plane and even heavy objects can slide easily on ice. In spite of their mobilities these heavy objects cannot be lifted easily because they are held by strong gravitational forces.

The proton is the most mobile particle in aqueous systems but it is held by forces (energy of hydration) which are far greater than those acting between other ions and the water.

The mobility of an electron, i.e., the electrical conductivity, is greater in metallic silver than in sodium. Nevertheless, the energy which is necessary to remove an electron from silver (ionization potential) exceeds that of sodium.

In an earlier paper[15] we commented on this fallacy which caused A. Bondi[16] in his discussion of the low viscosity of fused NaCl to write, "One might conclude that the motion of ions in flow takes place within a uniform electrostatic field and is restricted only by van der Waals' forces." The high boiling point of fused NaCl, however, reveals the presence of much stronger forces in such a melt than the van der Waals' forces which are active between neutral NaCl molecules.

Another fallacy with respect to rate phenomena concerns the geometry of the system before and after the reaction. Crystallographers speculated on the reason for the rapidity of the high-low transformation of quartz as compared with the sluggish change of quartz into tridymite and cristobalite. This speculation led M. J. Buerger[17] to the erroneous conclusion that transformations which involve only minor changes in the geometry are fast but those which involve a major change of the geometry are sluggish. This applies to the modifications of silica, but it is not generally true. The change of the red form of HgI_2 into the yellow form above 126°C is a fast transformation in spite of the crystal structures of the two forms being very different. There are good reasons for assuming that fused silica has a structure which resembles that of cristobalite. This assumption is supported by the low heat of fusion, the small change of volume and the fact that both vitreous silica and high-cristobalite have similar coefficients of thermal expansion. Nevertheless, pure vitreous silica does not devitrify rapidly.

III. Factors Controlling Nucleation and Glass Formation

"A theory is never overthrown by contradictory facts; it is only overthrown by a better theory".

J. B. Conant[18] (1947)

In retrospect it is truly amazing to see how glibly glass technologists accepted the theory that glass formation requires a tetrahedral coordination of cations and sharing of at least three of the corners with other tetrahedra in order to build up a three-dimensional network.

Objections to Zachariasen's theory were voiced strongly only within the first few years after its publication. It seems that the constant repetition of his rules in many publications changed them into a "truism" which nobody cared to examine more closely. Our analysis of the conditions of glass formation (Part I of this series) revealed that among the four major factors which different authors considered to be pertinent for the formation of a stable glass by a simple compound only Hägg's shape factor retained its significance.

Glass formation is the result of the lack of nucleation and nucleation is impaired by rapid cooling, high activation energy of nucleation, and low liquidus temperature. There is no obvious relation between the activation energy of nucleation of a melt and its thermodynamic properties, in particular the average bond strength as revealed by the heat of dissociation, the field strength of the cation, or the lattice energy of the compound. There is also no valid relation between the rate of nucleation and the energy content of the compound in its crystalline and its molten states. As far as the geometry is concerned a glass as a supercooled liquid resembles the structure of the substance in the molten state. However, the structure of the molten state may differ very much from that of the corresponding crystal (sulfur) or it may bear a very close resemblance to the crystal structure (cristobalite). This means that *glass formation is neither a function of the magnitude of the energy difference between crystal and liquid nor of the magnitude of the structural difference between crystal and liquid.*

1. The Rate of Cooling.

The paramount importance of the cooling rate of a melt on its ability to form a glass is well understood. A melt may have a composition which would not permit its use for the manufacture of window glass or containers but which would be well suited for making glass fibers or small glass beads.

Because of the importance of the cooling rate on glass formation one cannot arrive at an absolute classification of systems into those which are glass-forming and others which are not unless one standardizes the rate of cooling. The rate of cooling can be changed only within certain limits which depend upon the quantity and the shape of the sample. It is unfortunate that not all workers who report on new glass compositions mention in their papers the quantity of the substance which they were able to obtain as a glass.

When Brekhovskich[19] (1959) reported on his new high Bi_2O_3- containing glasses he used ternary diagrams in which the fields of glass formation were given for gram as well as for milligram quantities.

2. The Liquidus Temperature

The importance of the absolute melting point of a substance or the liquidus temperature of a system with regard to its glass formation should be obvious. Above this temperature nuclei cannot form; therefore, the substance can be kept at any temperature above its liquidus temperature indefinitely without nucleation and crystallization occurring. Only below this temperature can the probability of nucleation and crystallization reach a finite value.

As far as the rates of these processes are concerned, the absolute temperature enters all mathematical expressions which describe rate phenomena, usually in the form of the factor $e^{-E/T}$ in which T is the absolute temperature and E an energy term representing the height of the barrier which the system has to overcome in order to react. In spite of the simplicity of this relation the absolute liquidus temperature has been ignored by most scientists who made an attempt to relate the ability of a system to form such a glass with parameters such as its geometry (Goldschmidt)[20], the energy difference between a periodic and a random structure (Zachariasen)[21], the electronegativity of the cations (Stanworth)[22], or the energy of the bonds between neutral atoms (Sun)[23]. The paramount importance of the liquidus temperature for glass formation accounts for the facts that:

1. The high melting carbides, nitrides, silicides and borides do not form glasses,
2. Glass formation in the temperature region above 1500°C is rare, and
3. A large number and a great variety of substances melting around 100°C or below are known to form glasses.

3. The Activation Energy of Nucleation

The concept of an energy of activation is the outgrowth of experimental work. When scientists became interested in the rates at which two molecules A and B react they were faced by the puzzling question: If A can react with B to form AB, why does this reaction not always take place instantaneously, why does it require times which are very long as compared with the frequencies at which the molecules A and B collide in a gas or in a solution?

Svante Arrhenius (1899) supplied an answer to this question. He proposed that not all molecules A and B can undergo a chemical reaction when they collide. He postulated that in order to be able to react, these molecules must have a certain minimum kinetic energy which can be considerably higher than their average energy. In order to react, A and B have to be in an "active state". Hence, the rate of a reaction depends upon two factors, (1) the number of collisions per unit time Z, (2) the fraction of the molecules which are "active", i.e., those whose energy exceeds that of the average molecules by the quantity E.

According to the laws governing the statistical distribution of the kinetic energy of molecules, the fraction of molecules whose energy exceeds the average energy by the value E is given by the expression.

$$e^{-E/RT}$$

in which R is the gas constant and T the absolute temperature. The rate of a reaction should depend, therefore,

(*Continued on page* 590)

A method of analysis for gas contents in glass has been developed, which gives more accurate results than those previously reported. By this improved method, the evolution velocity of gases contained in some glasses of the Na_2O-CaO-MgO-SiO_2 system was measured at various extraction temperatures. The gas evolution was found to be an equilibrium phenomenon. Also, the behaviors of the gas contents in glass and in metal were compared. The gas behaviors in both are considered as similar phenomena.

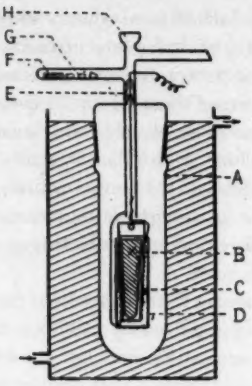


FIG. 1. Extracting apparatus.

Study of Absorbed Gas Components in Glass*

By Tsuneo Okamura and Tadoru Uno

RESEARCH LABORATORY OF THE ASAHI GLASS COMPANY, TSURUMI-KU, YOKOHAMA, JAPAN

Translated by T. J. WHANG and C. H. GREENE
Glass Technology Department, Alfred University

● AT THE BEGINNING of the fusion of glass a large amount of gas is evolved either from the decomposition of the batch or from the evaporation of the water content of the batch. Most of it is evolved as bubbles, but there still remains a large amount of gas in the glass.[1, 2] The gas content of the glass not only has a close relationship with bubbles in the glass (which is important for the quality of glass) but it also has an effect on the color, viscosity, surface tension, transparency, and other characteristics 3, 4, 5, 6, 7, 8, 9 of the glass as well.

As indicated above, the gas content of the glass depends in a complicated way on the composition of the batch and on the fining during melting. Because it is not possible to say just what state the gas in the glass is in, a study of the gas in glass has been attempted on a qualitative basis.

In order to understand thoroughly the relationship between gas and glass it would be important to know the state of the gas evolved. Since this study must be carried on at high temperatures and in a high vacuum system, this involves various difficulties.

Up to the present, only a few investigations of the gas composition by analysis have been carried out. After studying previous experiments and improving Dalton's method,[10] the authors obtained interesting results on the states of gas in glass.

Gas Contents

Generally gas molecules are adsorbed on a metal surface in the atomic state. Diffusing into the metal

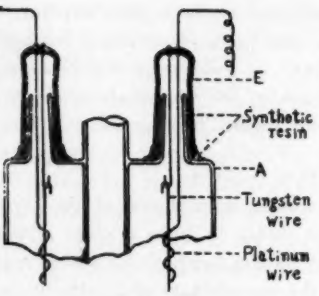


FIGURE 2

lattice, some of the gas becomes combined with other molecules to form chemical compounds. Many studies have been made on the gases present in metals; however, it is doubtful that gas behaves similarly in glass

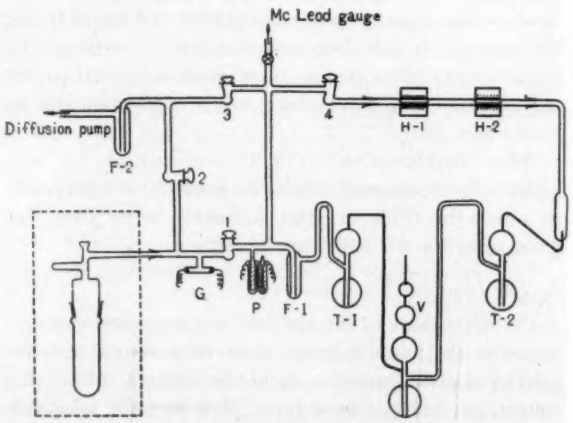


FIG. 3. Analytical apparatus.

*Research Laboratory Reports, Asahi Glass Co. 2, 1-10 (1952).

for the structure of glass is not clearly understood.

Gas is associated with glass in two different ways; some gas adheres to the surface of the glass, and some is dissolved in the glass.[11,12,13] The former type of association was studied as a desorption phenomenon at temperatures below the softening point of the glass and also from the point of view of a monomolecular layer on the glass surface or of several adsorbed layers.[14] The gas that adheres to the surface is quite insignificant compared with that dissolved in the glass, but for the study of glass surface phenomena it is highly significant. The latter is important in connection with the refining of the glass.

Allen and Zies[15] studied the gas content of glass and analyzed the gas evolved from a glass sample heated on a platinum boat in a fused silica tube at 1200°C. A constant vacuum was maintained. They indicated that most of the gas represents ignition loss. Their work was followed by that of Washburn,[16] who studied the gas content of glass but failed to provide for the detection of H_2O.

Salmang and Becker[17] determined for the first time the water content which they considered to be an important part of the gas dissolved in glass, but they encountered many difficulties. Dalton applied the physical method of low temeperature fractional distillation to the analysis of the gas content of glass and also improved the method of heating the sample. Hahner[18] studied window glass for the first time, but did not separate CO_2 and SO_2. Shadduck and Zee[19], who, in general, applied Dalton's method, studied mainly various kinds of optical glass.

Adding a few improvements to Dalton's method, the authors set up apparatus which is convenient for heating and also gives very accurate analytical results.

Apparatus

Analysis of the gas in glass was carried on by evolving the gases dissolved in the sample by fusion, at a high temperature in vacuum. Hence, there are two sections in the apparatus: one, the vacuum furnace for extracting the gases from the glass; the other, the analytical apparatus.

Furnace for Extracting Gases

In this part of the apparatus the gases in the glass are evolved by heating above 1000°C. in an evacuated vessel with the pressure below 10^{-3} mm. of Hg. The container may be heated either from outside or inside. Heating from the outside requires a vacuum container which can withstand high temperature without evolving gas from its substance or allowing gas to penetrate it and which can be attached to a cooling system. When heating in the container, the heating coil must be firmly attached to the container to prevent over-heating the rest of the apparatus by the heavy current and heat flow from the crucible. Since the authors obtained good results in attaching a heating coil, the internal heating method was used for this study.

The extraction part is shown in Fig. 1. The high vacuum extraction chamber "A" is made of a transparent fused silica tube because the heating unit "C" which is placed in it, heats to over 1400°C. The outside wall is cooled with water because of radiation from the heater. The platinum crucible *B* in which the sample is melted is made long (80 mm. x 16 mm. diam.) to prevent overflow being caused by the vigorous evolution of gas from the sample at the start. The heating unit "C" is a sillimanite porcelain tube, vitrified at high temperature, which does not dissolve the evolved gas and has a large number of holes for the sake of heating efficiency. The heater is made from platinum wire (0.7 mm. in diameter). The heating unit is surrounded by another sillimanite tube "D" to conserve radiant heat. The convex part of the silica tube is covered with a platinum cap "E" cemented with heat resistant synthetic resin as shown in Fig. 2. Platinum wires are attached to the outside and inside of the cap and tungsten wires

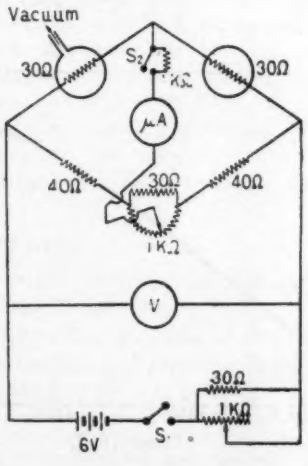


FIG. 4. Pirini gauge.

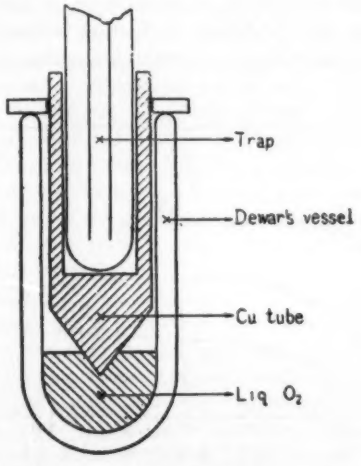


FIG. 5. Trap.

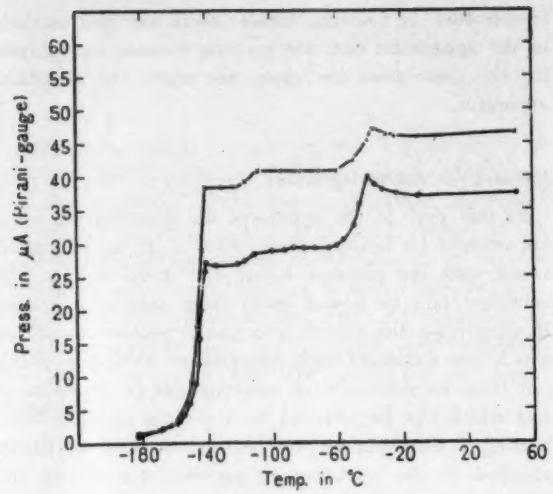


FIG. 6. Vapor press. vs. temp.

attached to the cap hold the heating unit so that its weight is not supported by the platinum wires. The attached part is water cooled.

The glass sample *G* in the side tube is pushed into the platinum crucible when the extracting temperature is reached by means of a piece of metal *F* in the tube, which can be moved by an outside magnet. The temperature of the crucible is measured by an optical pyrometer through the top of the center tube *H*.

Analytical Apparatus

Gases discharged from the extracting apparatus are analyzed here. Gases dissolved in glass may be analyzed by microanalysis, several methods having been studied up to the present. The analyses must be carried on continuously and rapidly. Therefore, the physical method of gas analysis is most suitable and in addition is highly accurate. Moreover, the components of the gas dissolved by glass have properties suitable to this kind of analysis so that the microanalysis of gas based on low temperature fractional distillation is used.[20]

The diagram of the analytical apparatus is shown in Fig. 3. The gases from the extracting part are transferred by the Toepler pumps *T-1* and *T-2* and condensed in the trap *F-1*, which is cooled with liquid oxygen. If the temperature of the trap is raised at the proper rate, various kinds of gases are separated at different temperatures. Pressure in the apparatus is measured continuously with the Pirani gauge shown in Fig. 4. Manganin coils are used in the bridge to minimize the effects of temperature changes. By changing switch S_2 more accuracy could be obtained at low and high pressures.

The bridge current of 1 microampere was measured by a microammeter so that high accuracy could be obtained over the range from 10^{-1} to 10^{-3} mm. of Hg. As shown in Fig. 3, by using a McLeod gauge to supplement the Pirani gauge and by using the Geisler tube (G) occasionally, the vacuum could be checked continuously with high accuracy. *V* is a series of gas measuring bulbs, and *H-1* and *H-2* are hard glass tubes for absorbing non condensable gases. These are detachable. Oil pumps are used for the exhaust of the analytical apparatus as shown in the figure.

Procedure and Gas Analysis

The extracting apparatus was set up as in Fig. 1 and after it had been thoroughly exhausted, a sample of about 2 grams was fused at high temperature. The gases evolved from the apparatus were analyzed. The details are as follows.

Procedure

After powdered glass and oil have been removed from the surface of the sample, it is placed in the tube as shown in Fig. 1. With the extraction part connected to the analytical part, the apparatus is thoroughly exhausted to 10^{-4} mm. of Hg by an oil diffusion pump. The apparatus is left overnight, and after high vacuum is obtained, the furnace *C* is heated while the exhaust pump is running. The pumping is continued for an hour after the extraction temperature is reached, and the

(*Continued on page* 585)

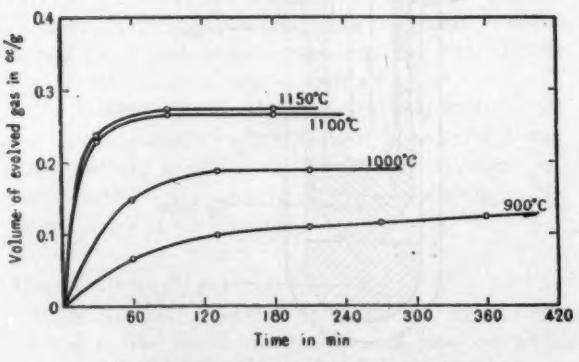


FIG. 7. Amounts of gas evolved vs. temperature.

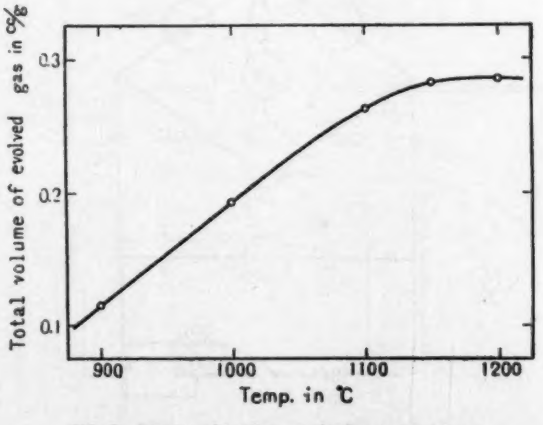


FIG. 8. Amounts of total gas evolved vs. temperature.

Bibliography on Glass Structure*

PART IV

94. N. K. Dertev

'Atomic Structure of Glass," Stekol'naya Prom., 16, No. 2, 16-18 (1940).

Extensive investigations were made on the density, hardness and viscosity of glass and its transformation into a brittle state in connection with the atomic structure when hot and upon cooling. The investigation was carried out in the light of the work of Laue (1912) and recent investigations according to whom a lattice of Si glass is made up of Si atoms each surrounded by 4 oxygens forming a tetrahedron.

95. O. K. Botvinkin

"Glasslike State," Izvest, Akad. Nauk. S.S.S.R., Ser. 4, 600-603 (1940); Cer. Abs. 20, 261 (1941).

Crystals discovered in glasses are not structural elements of them but the products of devitrification. The aggregates of simple or associated molecules composing glass are homogeneous in their chemical composition the temperatures of complete aggregation being different for each type of grouping. Binding between molecules and aggregates of glass is considerably weaker than that between atoms in a molecule of the silicates.

96. L. A. Afans'ev

"The Application of Diffraction of Rapid Electrons to the Investigation of the Structure of Silicate Glasses," Trudy Tret'ego Soveshchaniya Eksptl. Mineral. i Petrog. Inst. Geol. Nauk. Akad, Nauk. Akad. S.S.S.R., 265-8 (1940).

Electronograms of colored glasses and of Fourcault glass were obtained on the electronograph constructed according to the Thomson method, as modified by Yakoviev. The rings of the Fourcault glass electronograms fit satisfactorily the hexagonal lattice with a constant c/a = 1.63, but with various c and a values for different cases. This supports the theory of Zachariasen.

97. B. E. Warren

"X-ray Diffraction Study of the Structure of Glass," Chem. Rev., 26, 237-55 (1940).

The glass forming properties of SiO_2 are due to two features resulting from the coordination scheme. First, even in the melt there is probably a strong tendency for each Si atom to surround itself by four oxygen atoms and for each oxygen atom to bond between two Si atoms. There are thus enough linkages in the melt to stiffen it and to give it the high viscosity which prevents the atoms from rearranging themselves in the orderly fashion necessary for crystallization. Secondly, the fact that each oxygen atom is bonded to only two silicon atoms makes the structure so flexible that the random network is almost as stable as a crystalline arrangement. For oxides to form glasses it is essential that each anion shall be bonded to not more than the two glass forming cations. The oxides found in the common glass may be classified as one network former and two modifiers. SiO_2, B_2O_3, P_2O_5 and GeO_2 are the standard network formers, while oxides such as Na_2O, K_2O, CaO, BaO and PbO modify the properties of the glass by changing the ratio of total oxygen atoms to network-forming cations. In the case of sugars or glycerol, glasses are formed by the random bonding of OH groups on neighboring molecules.

98. B. E. Warren

"Summary of Work on Atomic Arrangement in Glass," J. Am. Ceram. Soc., 24, 256-61 (1941).

The present picture of the atomic arrangement in glass has developed from four kinds of information, namely, the laws of physical chemistry, the x-ray diffraction study of glass, the various measured physical properties of glass and the kinds of materials and the ranges of composition in which glass-forming properties exist. X-ray diffraction on studies establish the predominant type of bonding in glass, for example, the tetrahedral bonding in silicate glasses. Secondary structural features such as those which change with annealing or condition do not show up in the x-ray pattern. Most of the proposed structures are those which are suggested and are partially substantiated by x-ray studies, those which fit the laws of crystal chemistry, and those which seem best able to explain the physical properties of the glass. The preliminary theory of immiscibility in glass systems has been extended to include a consideration of the temperature dependence. A study of thermal expansion in terms of the number of glass-forming bonds allows a simple correlation between expansion coefficients in the silica-boric oxide and soda-boric oxide systems. The same kind of considerations used in discussing immiscibility may be used to give a quantitative treatment of the change in the coordination number of the boron atom when boric oxide is present with soda.

*This series will be completed next year. Reprints will be available at nominal cost, provided there is sufficient interest. Order from Reprint Dept., THE GLASS INDUSTRY, 55 West 42nd Street, New York 36, N.Y.

99. A. Dietzel

"Structural Chemistry of Glass," Naturwissenschaften 29, 537-47 (1941).

100. S. S. Lu and Y. L. Chang

"Structure of Vitreous Silica," Nature (London) 147, 642-3 (1941).

101. E. Kordes

"Physicochemical Researches on the Fine Structure of Glasses, IV, Changes of the Fine Structure in the System P_2O_5-ZnO," Z. Physik. Chem., B50, 194-212 (1941); Cer. Abs. 135 (1943).

The curves of the refraction and density of the glasses in the P_2O_5-ZnO system show a break at 50 mol %. The curve of the mol refraction of the zinc phosphate glasses is smooth at 60 mol % ZnO. The conclusion is that the ZnO-P_2O_5 glass has a silica or cristobalite structure. By means of the ionic radii and with this hypothesis the observed curves of refraction and density can be calculated up to 50 mol % ZnO with great, and above 50% with complete accuracy.

102. A. Dietzel

"Crystal Chemistry View of the Constitution of Glasses," Naturwissenschaften, 29 (1941); Cer. Abs. 141 (1942).

The principal difference between a glass and crystal is that the ion groups are arranged in different degree of order, not that these groups are different in themselves. Two cases of coordination changes of ions taking place in crystals as well as in glasses are distinguished. In the first case a saturated coordination changes to an unsaturated one; thus a decrease in negative field around the cation is allowed. If colored ions are involved, this change causes a shift toward longer wave of the absorption edge. The second case is a change from a higher saturated coordination to a lower saturated one with increase in negative field around the cation. The absorption edge shifts toward shorter wavelengths.

103. J. Biscoe, M. A. A. Druesne, and B. E. Warren

"X-ray Study of Potash-Silica Glass," J. Am. Ceram. Soc., 24, 100-102 (1941).

X-ray diffraction studies have been made of two samples of potash-silica glass whose composition is 20.9% and 29.1% K_2O by weight. A Fourier analysis of the intensity curves indicates a structure similar to that found in soda-silica glass. Each silicon is tetrahedrally bonded to 4 oxygen ions, with each oxygen bonded either to 1 or 2 silicons. The K ions are situated in holes in the silicon-oxygen network with an average of about 10 oxygen neighbors.

104. J. Biscoe, A. G. Pincus, C. S. Smith and B. E. Warren

"X-ray Study of Lime-Phosphate and Lime-Borate Glass," J. Am. Ceram. Soc., 24, 116-19 (1941).

X-ray diffraction patterns were made of two lime-phosphate glasses containing 20 and 28% CaO by weight and of one lime-borate glass containing 25% CaO. Fourier analysis of these patterns were carried out and the radial distribution curves plotted. In the lime-phosphate glasses each P is tetrahedrally bonded to 4 oxygens at a distance of 1.57 A., and each O is bonded to either one or two P atoms. The Ca ions are situated in holes of the P-O network and have about 7 oxygen neighbors. In the lime-borate glass, some of the borons are triangularly bonded to 3 oxygens, and the others are tetrahedrally bonded to 4 oxygens.

105. J. Biscoe

"X-ray Study of Soda-Lime-Silica Glass," J. Am. Ceram. Soc., 24, 262-64 (1941).

X-ray diffraction patterns of three compositions of soda-lime-silica glass were made, and radial distribution curves for the three glasses were obtained from Fourier analysis of the patterns. The results indicate that the silicon atoms are tetrahedrally bonded to 4 oxygens. Each oxygen is bonded to either 1 or 2 silicons. If each sodium is assumed to be surrounded by 6 oxygens, each calcium must be surrounded by about 7 oxygens. The structure is similar to that of soda-silica glass except that some of the sodiums are replaced by calciums. A qualitative correlation of the structure with density and coefficient of expansion is made.

106. A. Dietzel

"Relation Between Expansion Coefficient and Structure of Glasses," Glastech. Ber., 19, 319-25 (1941).

107. B. E. Warren

"Basic Principles Involved in the Glassy State," J. Applied Phys., 13, 602-10; Technology Review 43, 253-5, 273-4 (1942).

The structures of various glasses as revealed by crystal chemistry and x-ray diffraction patterns are described. Silicate glasses, effects of disorder in vitreous silica, immiscibility in the lime-silica system, and the boric oxide anomaly are discussed.

108. A. Smekal

"The Vitreous State and Chemical Bonds," Verh. D. Phys. Gps., 23, 39 (1942).

109. Eric Preston

"Structure and Constitution of Glass," J. Soc. Glass Tech., 26, 82-107 (1942).

Some consequences are considered of the conclusion that in viscous silicates 4 oxygen atoms are attached to a silicon atom forming a tetrahedral unit, which is the fundamental unit of structure in glassy as well as in crystalline silicates. It is pointed out that there are certain reservations, as yet incompletely considered, attaching to the random-network theory, for as the concentration of silica decreases the minute particle size completely satisfying all the requirements of ratios of silicon, oxygen and metal atoms decreases also until at 33.3 mol % silica individual tetrahedra must exist. A preliminary attempt is made to correlate this decreasing particle size or coordination group, with known physical and chemical properties of glasses. It is suggested that before a harmonious theory of the constitution of glasses can be set out much more must be known

of the constitution of simpler solutions; x-ray investigations on glasses have to some extent gone ahead of this vitally necessary preliminary work. The persistence of the silica tetrahedra in glassy silicates is the significant fact which emerges from the x-ray work, and on this simple result alone a plausible explanation is afforded of many of the properties of glasses. The problem of the manner of bonding of the metal atoms is much less certain and requires further research.

110. E. A. Porai-Koshitz

"Structure of Vitreous Substances," Compt. rend. acad. sci. U.R.S.S., 36, 267-9 (1942) (in English).

The author investigated a so-called "French molybdenum" glass (SiO_2 63.3, B_2O_3 26.55, Na_2O 7 and As_2O_3 1.15% by weight) and found that it loses the Na_2O-B_2O_3 constituent on treatment with acid; this leaves a "macrofilm" retaining the properties of glass. X-ray diffraction studies showed a definite additivity of the structures of vitreous silica and of the Na_2O-B_2O_3 constituent which forms the initial complex glass. Heating the initial glass at 660° for 4 hours with subsequent quenching shows opalescence which may be ascribed to growth of the Na_2O-B_2O_3 crystallites. This is substantiated by heating initially to 700° for 30 minutes and quenching, when lines are produced which do not all correspond to quartz, tridymite or cristobalite, but are characteristic of all Na_2O-B_2O_3 compounds in the crystalline and in the vitreous state. The second conclusion is that of an independent growth of the orderliness of crystallites of one structure within another; this supports the crystallite hypothesis of the structure of glasses.

111. A. G. Pincus

"Glass From the Atomic View," Ceram. Age, 39, 38-41 (1942).

Recent work on the atomic structure of glass has aided in explaining many known facts about glass and may point to new developments. New concepts such as interionic distance, ionic radii and ionic potentials are discussed.

112. J. S. Lukesh

"Distribution of Metallic Atoms in Two-Component Glasses," Proc. Natl. Acad. Sci. U. S. 28, 277-81 (1942).

Radial distribution curves were obtained by Warren and his school for soda-silica, soda-boric oxide, potassium oxide-boric oxide, pure silica and pure boric oxide, but none of these curves gave the metallic atom distribution. When the ordinates for pure silica were subtracted from those of the curve for soda-silica glass, a differential radial distribution curve was obtained, eliminating all peaks common to both curves. In this way, the Na-O distance in soda-silica glass was found to be 2.35 A. In the ordinary distribution curve this peak was combined with the O-O distance of 2.65 A. The Na-O peak remains constant with varying glass composition, but the area beneath the curve increases with increasing soda content. A second peak is probably due to Na-Na. Errors are exaggerated in the differential curves.

113. R. L. Green

"X-ray Diffraction and Physical Properties of Potassium-Borate Glasses," J. Am. Ceram. Soc., 25, 83-89 (1942).

The composition of the glasses studied ranged from 0 to 40% by weight K_2O. Calculations based on x-ray diffraction patterns showed a change from 3 to 4 fold coordination with an increase to 22% K_2O. The K ions formed single bonded oxygens and thus weakened the structure with a K_2O content exceeding 22%. With 20-25% K_2O the coefficient of thermal expansion was a minimum showing that a majority of the B atoms were in 4-fold coordination.

114. A. Dietzel

"Relation Between the Surface Tension and the Structure of Molten Glass," Kolloid Z., 100, 368-80 (1942).

The surfaces of molten salts and glasses, considered structurally, contain cations and anions. Whereas in the interior each cation is surrounded by a number of anions, varying regularly from ion to ion, so that as a statistical average a definite coordination number arises, the coordinations in the surface, a small complex-formation occurs, are partly incomplete. Surface tension is discussed on this basis and the reason for surface tension increases and decreases with various cations and anions is discussed.

115. H. P. Rooksby and L. A. Thomas

"The Structure of Vitreous Silica," Natura, 149, 273-4 (1942).

116. A. E. Badger, H. C. Johnson and J. O. Kraehenbuehl

J. Am. Ceram. Soc., 25, 395-401 (1942).

A series of soda-boric oxide glasses were melted in platinum and transmission curves run. An abrupt rate of change of transmission with temperature occurs at or near the transformation temperature. The break in property composition curves at about 15% Na_2O is shown clearly by the transmission curves. Glasses containing approximately 10% and 20% Na_2O correspond to stable configurations. The use of color indicators to note changes in structure seems to be a reliable method.

117. B. Schweig

"The Constitution of Glass," Glass, 20 (10) 257-59 (1943), II, III ibid (8) 200-202 (9) 227-29; Cer. Abs. 8 (1944).

Historical.

118. E. A. Porai-Koshitz

"The Structure of Complex Glasses," Compt. rend. acad. sci. U.R.S.S., 40, 346-9 (1943) (in English); cf. C. A. 37, 2895[9], 3891[2] (1943).

The additivity method for analyzing the x-ray scattering curves of complex mixtures was used to investigate scattering curves calculated in absolute units from experimental data obtained by x-ray investigation of various vitreous systems. The curves for the system silica-boric oxide indicate absence of chemical compound formation; the scattering curves can be regarded as the sum of the curves for vitreous silica and boric

oxide. The curves for 5 glasses consisting of 19.0-34.6% Na_2O and 81.0-65.4% SiO_2 indicate the presence of SiO_2 and Na_2SiO_3. Glass is regarded as non-homogeneous in detail and as containing areas with a relatively better regulated atom arrangement (crystallites). It is in these areas that chemically heterogeneous elements of independent structures occur in complex glasses.

119. J. I. Gerlovin

"Glass Structure According to Infrared Absorption Spectra," Compt. rend. acad. sci. U.R.S.S., 38, 126-7 (1943) (in English).

Absorption spectra of quartz and various glasses in the 8 to 14 μ region support the viewpoint that silicate glasses consist of tetrahedral SiO_4 forming a ring structure. With the addition of metallic oxides, absorption bands become more diffuse and are shifted to greater wavelengths; the heavier the metal, the more pronounced is the effect.

120. A. Dietzel

"The Structure of Silicate Glasses," Naturwissenschaften, 31, 110-12 (1943).

Dietzel discusses the structure of silicate glasses based upon the extraction of alkali by acids and water. He concludes that his results are explained by the shielding of alkali atoms by SiO_4 groups. He shows that the technical glasses usually have the cation completely surrounded by the anion structure.

121. W. A. Weyl

"Colored Glasses, I, Constitution of Colored Glasses," J. Soc. Glass Tech., 27 (122), 133-206 (1943).

122. Ida Makoto

"X-ray Investigation of Potassium Oxide-Silica Glasses," Proc. Phys. Math. Soc. Japan, 26, 55-65 (1944).

Potassium oxide-silica glasses were examined by x-rays to test the irregular-network theory of Zachariasen-Warren and the deformed-crystallite theory of Randall-Valenkov. The interpretation of intensity curves of potassium oxide-silica glasses by means of the crystalline theory is not so simple as Valenkov's idea.

123. N. Kreidel

"Recent Studies on the Fluorescence of Glass," J. Optical Soc. Amer., 35 (4) 249-57 (1945); Cer. Abs. 163 (1945).

Kreidel discusses the use of fluorescence as an indication of the location of the unit and the nature of the unit surroundings. Structural changes in the glass with heat treatment or different structures in glasses of different composition effect the energy and therefore the color and intensity of the fluoresence. Fluoresence is effected by structural changes in the glass as follows: (1) The more the fluoresence center is disturbed by the surroundings, the more is intensity decreased and the wavelengths shifted toward red. Interpretation of these changes can extend the evidence of x-ray analysis to more complex glasses. (2) The narrowing of fluoresence bands indicates increasing symmetry in the environment and aids the evaluation of structural differences between crystals and glasses of equal composition, especially as a function of temperature. (3) Fluoresence of longer duration accompanies increasing viscosity and less frequent collisions.

124. W. A. Weyl

"Use of Color and Fluorescence Indicators for Determining the Structure of Glass," J. Applied Phys. 17, 628-39 (1946).

Analogies are drawn between the colors of glasses and of liquid solutions as governed by changes in the kinds and concentrations of solvents and constituents. Light-absorption curves are shown for Ni^2 in a K silicate glass, and in a NaLi silicate glass, and for Cr glasses melted under oxidizing and reducing conditions. The effect on color of the sizes and charges of various ions is discussed.

125. Kuan-Han Sun

"Glass-Forming Substances," Glass Ind., (11) 27, 552-55 (1946).

126. J. M. Stevels

"Physical Properties of Glass and Its Structure," Nederland. Tydschr. Natuurk., 12, 257-78 (1946); cf. C. A. 41, 4901^b (1947).

A review of properties of glass on the basis of molecular arrangements of constituents. Volume relations and electrical properties are dealt with.

127. J. M. Stevels

"The Physical Properties of Glass in Relation to its Structure," J. Soc. Glass Tech., (137) 31-54 (1946).

A fairly extensive account is given of the knowledge we have at present of the structure of glass in general.

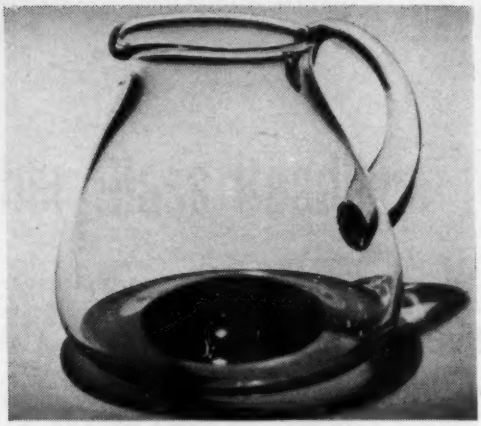
On this basis some physical properties are discussed. The density of normal glasses can be calculated satisfactorily by means of a formula containing only two constants, both of which have a well-defined physical meaning. One of these constants can give valuable information about the structure of the glass, especially about the way in which the excess oxygen is taken up by the network.

128. J. E. Stanworth

"The Structure of Glass," J. Soc. Glass Tech. (137) 54-67 (1946).

In the past, the absence of any fundamental method of predicting the chemical composition necessary to devise a glass with required physical properties has meant that the development of new glasses has involved long and patient investigation based on the results of earlier empirical knowledge, and accumulated experience. The development, however, of a theory of the structure of glass by Warren and his co-workers leads one to hope that in the future, the production of new glasses will depend increasingly upon a fundamental understanding of the relation between composition, structure and physical properties.

(Continued in November)



Jug, designed by Per Lutken, made by Holmegaards.

Per Lutken

Danish Glassware Exhibition

● CONTEMPORARY DANISH GLASSWARE will be on display later this month at the Metropolitan Museum of Art, as part of the "Arts of Denmark" exhibition which will include Danish arts and crafts from prehistoric to present times.

The exhibit will be officially opened on October 14 by King Frederik and Queen Ingrid during their 14-day State visit to the United States (October 4 to October 17), as guests of President Eisenhower.

Occupying some 10,000 square feet of space in the Museum, the exhibition will include objects of the Stone and Bronze Ages and Viking Days through examples of Medieval, Renaissance, folk and modern art. The contemporary section—almost half of the exhibit—is devoted to glass, modern furniture, metalwork, ceramics, porcelain, textiles, embroideries and silver created by leading Danish craftsmen.

After January 8, the exhibit will be on display at other prominent Museums during a tour around the United States.

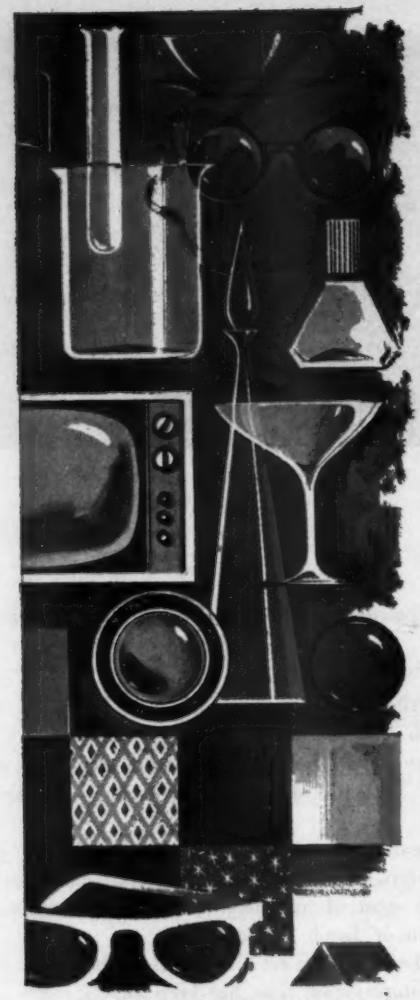
The glassware is a product of Denmark's two glass manufacturers, Holmegaards Glasvaerk, and Kastrup Glasvaerk; most of the pieces were designed either by Per Lutken or Jacob E. Bang.

Mr. Lutken has been art director of Holmegaards since 1942 and during that time has been developing a technique in glassmaking (see cover illustration) by which he strives to make use of the inherent qualities of glass. He has had separate exhibitions in Denmark, Norway,

(*Continued on page* 589)

This set is used in Danish celebrations. Each glass is filled with aqua vite and, while a toast is made, "must be held close to the breast." Then, it's "Bottom's up," and the empty glasses are turned upside down on the dishes until the next toast. Designed by Jacob E. Bang.

Jacob E. Bang



As uses have increased,
prices have lowered
for the large scale
commercial application of

LINDSAY RARE EARTH CHEMICALS IN GLASS AND CERAMICS

For Radiation Protective Glass, TV Tubes, Optical Lenses, Camera Lenses, Special Glasses:
Cerium Hydrate
Cerium Oxalate
Thorium Oxide
Lanthanum Oxalate
Lanthanum Oxide

For Colored Glass, Sunglasses, Goggles, Stemware:
Cerium Hydrate
Didymium Salts
Neodymium Salts

As Opacifiers for Vitreous Enamel:
Cerium Oxide
Cerium Hydrate

As Coloring Agents for Porcelain Enamels and Stains:
Praseodymium and Neodymium Salts

In Ceramic Control Materials for Nuclear Reactors:
Samarium Oxide
Gadolinium Oxide
Europium Oxide

In Electronic Ceramics:
Didymium Salts
Yttrium Salts
Gadolinium Salts

The broad line of rare earth chemicals, no longer "rare" but available from the LINDSAY CHEMICAL DIVISION in volume quantities and commercially attractive prices, has opened whole new vistas, bright with new marketing possibilities for the ceramic industry. LINDSAY rare earths have properties that change and improve the color of glass and ceramics, provide stability against radiation and electron bombardment, improve the optical characteristics of glass, and result in faster, more economical glass polishing. Research and development in commercial rare earths is a continuing program at the LINDSAY division. Concurrently, investigations into new applications by forward-looking users are leading to dramatic break-throughs in the economic aspects of these materials.

Write today for complete technical information from LINDSAY—*industry's leading source of rare earth chemicals.*

TRONA

LINDSAY CHEMICAL DIVISION
American Potash & Chemical Corporation
99 PARK AVENUE, NEW YORK 16, NEW YORK
3000 WEST SIXTH STREET, LOS ANGELES 54, CALIFORNIA

Fiber Glass Headliner for Cars

● ANOTHER IMPORTANT FIRST FOR FIBER GLASS—an acoustical headliner for automobiles—will appear this month in 1961 models of American Motors' Rambler and Ambassador cars. Co-producers of the new car ceiling are Johns-Manville Fiber Glass Corp. and Owens-Corning Fiberglas Corp.

If the product catches on, and there is every indication that it will, this could mean an annual fiber glass market of from $75 to $100 million, not only for use in cars, but also in busses, trucks, aircraft, and railway cars.

The average cost for each fiber glass headliner is somewhat under $10, taking into account the various sizes from station wagon down. This is more than the conventional cloth ceiling, per manufactured unit. Actually, though, the fully installed fiber glass headliner costs less than the cloth ceiling because the one-piece fiber glass unit is so easy to snap in place, in contrast to the conventional sewn fabric liners which must be held in place by a complicated system of listing wires.

When ready for installation, on the body assembly line in the automobile plant, the one-piece fiber glass headliner is passed through the windshield or back-light area before the glass is put in. The headliner is fitted into position below the steel top by two workmen, one on each side of the car body, who flex it slightly and snap it into the metal trim channels, in a matter of a few seconds. No other fastenings or adjustments are necessary.

The new headliner provides up to ¾" more head room in the car and, because there is just one piece, without seams, it gives the effect of a greater ceiling area, and more spaciousness in the car. Other advantages include a sound control, a wide choice of colors which help dress up the interior of the car, and a safety cushion, provided by the fiber glass.

Owens-Corning did some earlier work on headliners about five years ago but abandoned the research because there were too many technical problems at that time, and resins and molding processes had not been perfected to the level of today's standards.

This is the first one-piece fiber glass headliner and the first automobile product made of two types of fiber glass molded together in a sandwich, with a polyethylene film in the middle.

Some production problems still exist today in the molding and laminating procedures, but these are now being straightened out in the fabricating plants of Owens-Corning Fiberglas (Kansas City) and Johns-Manville Fiber Glass (Defiance, O.).

Production Method

The lay-up consists of three layers:

1. Fiber glass trim fabric. This is the finish, or inside ceiling, visible to the car passengers, and serves as a protective and decorative lining.
2. Thin polyethylene film. The fibers of layers (1) and (3) are mechanically impressed into each surface of the polyethylene film during the laminating process, and, in this way a strong bond is formed. The film also serves as a barrier and prevents the phenolic resin in the insulation from bleeding through and staining the fabric.
3. Two layers of unbonded fiber glass insulation. Each layer is 2 inches thick, before compression.

These three components are fastened to a special metal jig under spring tension, and the jig is moved on a track into a 40-ton press. After three minutes (the 4-inch lamination is compressed to ¾ inch), the finished, molded (untrimmed) headliner is removed from the press, inspected, transferred to a trim fixture for trimming; the dome-light hole is punched, and the finished product is removed from the fixture, inspected once again and, finally, packed in a corrugated box for shipment to the automobile manufacturing plant.

The fiber glass fabric is woven by J. P. Stevens & Co., Inc. and by Hess Goldsmith Co., Inc. The presses are made by Modern Pattern & Plastics, Toledo, O.

Left to right, Don L. Hinmon, senior vice president, Clinton B. Burnett, J-M president, and Fred W. Segerstrom, fiber glass automotive sales manager, inspecting first production headliners at company's Defiance, Ohio, plant. New 40-ton press is in background, and was designed specifically for headliner production. Workman, lower left, is transferring molded unit to trimming fixture.

New B&W REFRACTORIES FOR THE GLASS INDUSTRY

B&W's line of refractories has been enlarged by the addition of new heavy duty firebrick and new ramming mixes. These new products, now offered after many years of developmental and field experience, are specifically designed for superior service in port necks and walls, regenerator walls and crowns, checkers, rider arches and burner blocks.

FIREBRICK

★

KAO-HB

HIGH BURNED SUPER DUTY FIREBRICK

Fusion point 3220 F. This brick offers an excellent balance of properties to assure superior service. It provides approximately 5% more alumina content and lower total impurities than competitive brick. It has excellent spalling resistance.

KAO 60

60% ALUMINA FIREBRICK

Fusion point 3250 F. Provides higher hot load strength than any competitive brick. Spalling loss is only 1%.

KAO 70

70% ALUMINA FIREBRICK

Very low total impurities provide long life. Spall loss of only 2%.

RAMMING MIXES

★

MULRAM E

Use limit 3200 F. Alumina content—80%. This new ramming mix with extremely low permeability provides exceptional resistance to slag or molten metal penetration. High strength provides good erosion resistance.

MULRAM EF

Use limit 3100 F. Alumina content—80%. Similar to Mulram E but supplied in finer grain.

MULRAM CB

Use limit 3000 F. Alumina content —78%. A new chemically bonded dry ramming mix that provides greater strength at low temperatures, high modulus of rupture and excellent resistance to abrasion, slag and scale.

FOR COMPLETE PROPERTIES SHEETS and additional information on these new B&W Refractories products, write to The Babcock & Wilcox Company, Refractories Division, 161 East 42nd Street, New York 17, N. Y.

B&W

THE BABCOCK & WILCOX COMPANY

REFRACTORIES DIVISION

B&W Firebrick, Insulating Firebrick, and Refractory Castables, Plastics, Ramming Mixes, Mortars, and Ceramic Fiber.

• FIBER GLASS •

Fiber glass is extremely important to the reinforced plastics industry and comprises about 92 per cent of the reinforcing materials used. Sales of reinforced plastics rose 42.5 per cent in 1959 over 1958 and were prevented from going higher only by the shortage of fiber glass. Because of the important position fiber glass holds in this industry, we are this month reviewing a representative number of the 80 papers that were delivered at the Fifteenth Annual Conference on Reinforced Plastics held in Chicago in February. Products covered included radomes, missiles, firearm barrels, decorative laminates, structural panels, submarine superstructures, underwater weapons, filament wound structures, master models, pre-impregnated fabrics, and motor truck cabs.

CONFERENCE ON FIBER GLASS REINFORCED PLASTICS

● IT IS ESTIMATED that approximately one-fourth of the total output of glass fibers goes into the production of reinforced plastics. While twice as much probably enters into a variety of thermal insulation applications, it is believed that the fastest rate of growth among the several applications for glass fibers lies in the fiber glass reinforced plastics industry.

One evidence of the growing demand for glass fibers for the reinforced plastics field is the expanding output of textile glass fibers, a great portion of which enters into preparation of plastic-glass laminates. The data in Table I are from the Textile Economics Bureau.

Table I

TEXTILE GLASS FIBER OUTPUT

Year	Millions of pounds	Year	Millions of pounds
1949	8.2	1955	75.8
1950	23.5	1956	96.5
1951	34.5	1957	110.5
1952	45.0	1958	103.8
1953	50.3	1959	147.4
1954	59.2		

According to A. W. Levenhagen, chairman of the Reinforced Plastics Division of the Society of the Plastics Industry, Inc. (SPI), estimates for 1960 sales of fiber glass reinforced plastics range from 10 to 20 per cent more than the 264 million pounds sold in 1959. These estimates are held down by the speculation on how much new basic glass strand production will be available during the year. For 1965 sales are being projected at an annual rate of 525 million pounds, double the 1959 figure.

This rapid growth was demonstrated by the 15th Annual Exhibit and Conference in February. More than 1200 scientists, engineers, technicians, designers and technical sales people, by far the largest attendance in the history of this group, were present some 80 papers were given covering all phases of the expanding reinforced plastics industry.

Levenhagen, who is president of the Molded Fiber Glass Tray Co. of Linesville, Pa., pointed out that the division's annual meeting is unique in American industry because "it features in its technical papers the exchange of innermost production and processing secrets among industry people representing some 250 competing companies."

Large Epoxy Reinforced Plastic Structures

By A. G. Butler and A. W. Hawkins,

Union Carbide Plastics Co.

A giant reinforced plastic cargo carrier, built with a spray gun and capable of transporting a 40,000 pound payload by rail, ship or motor has been constructed and tested. Of epoxy-fiber glass construction, the 2,800 pound container weighs one-fourth less than a comparable aluminum carrier, is eight times as rigid as aluminum, and is very resistant to abrasion, fatigue, and chemical and salt water corrosion. One of the largest epoxy reinforced plastic containers ever built, it is 24 feet long, 8 feet wide and 8 feet high.

It can be bulk-loaded and then lifted by straddle carrier or ship's crane to a railroad flat car, flat-bed motor carrier, or shipboard. The carriers can be stacked five high for ship transport.

The prototype carrier consists of built-up epoxy-glass fiber panels 4 x 8 feet in size that are bonded to a steel

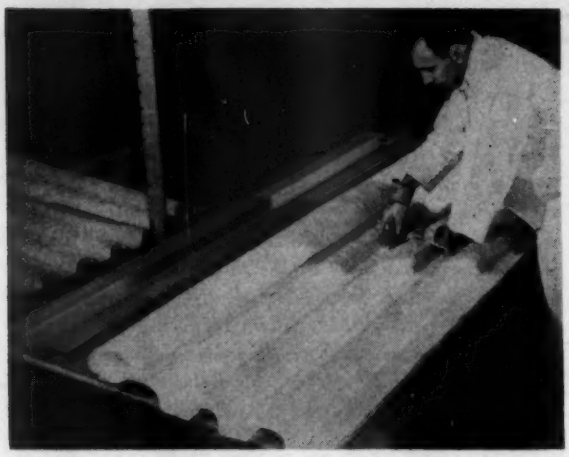


FIG. 1. Building epoxy-glass fiber cargo carrier. Step 1. Glass fiber mat is stapled to cardboard core before spraying with epoxy.

FIG. 2. Building epoxy-glass fiber cargo carrier. Step 2. Epoxy is sprayed over glass fiber.

frame. In future models about half the weight of the steel frame, or about 500 pounds, can be saved by eliminating the floor frame and using a monolithic floor of epoxy-glass. Additional savings may be realized also by use of epoxy-glass corner posts instead of steel posts.

Figures 1-4 show the steps in the construction of the carrier. After the panels are bonded to the steel frame, a curved sheet metal molding is bonded to all right angles in the interior and laminated with epoxy-glass covering. Manhole covers, intake and dumping spouts are added and the entire surface sprayed with an epoxy gel coat to form a tough, smooth surface that can be pigmented to any desired color. Figure 5 shows the carrier being loaded onto a flatcar.

Design, Fabrication and Erection of 140-Ft.-Diameter Honeycomb-Sandwich Radome

By George C. Fretz,

Goodyear Aircraft Corp.

Honeycomb sandwich panels fabricated of fiber glass reinforced plastic skin and edge reinforcements and Kraft paper honeycomb core are used for large truncated spheres to house the radar antennae for the BMEWS stations. The fiber glass presents a reduced electrical obstruction and forms a very strong, stable structure. The radome, a truncated sphere 140 feet in diameter and 116 feet high mounted on a ring 105 feet in diameter atop a 150′ x 150′ x 37′ high building, must withstand a 140 mph wind at –10°F. The temperature requirements are –65 to 160°F. It consists of 1646 modules or panels ranging from 25 to 36 square feet in area. each weighing an average of 125 pounds.

The field erection consists of bolting together the 6-inch-thick panels tier by tier from the inside of the sphere, all joints being caulked for weatherproofing as erection proceeds. After all panels have been installed, removal of several from an area near the base permits installation of the radar dish and drive.

The strength, electrical characteristics and moldability of the materials comprising the sandwich panels contribute to efficient and rapid production and erection of them into this huge structure.

Why Reinforced Plastics for Redstone Missiles.

By H. Haugan,

Chrysler Corp. Missile Division

A wide variety of fiber glass reinforced plastic components are being used in the Redstone missiles. This material has enhanced the:

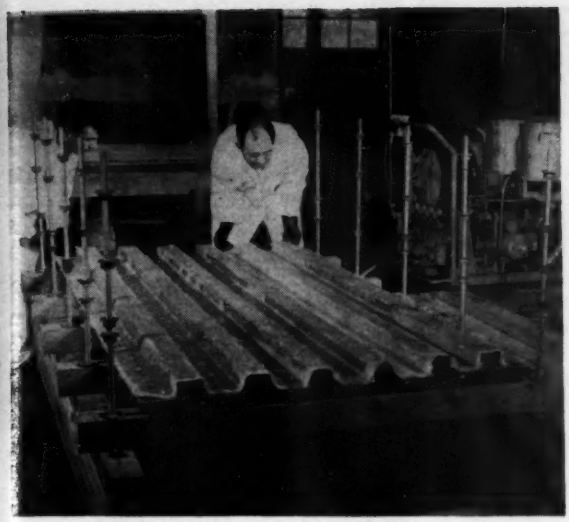
1. Ease of manufacture—design changes can be facilitated by forming parts from low-cost tooling, for example.
2. Elimination of operations such as drilling, bending, machining, riveting, bolting, welding, degreasing and painting.
3. Reduction of assembly time.
4. Vibration dampening.
5. Insulation and de-icing properties.
6. Reduction of weight—for some applications, weight savings of 40% have been realized.
7. Reduction of cost.

High Temperature Plastics Current Capabilities and Future Prospects.

By Harry Raech, Jr.,

Norair Division, Northrop Corp.

The potential applications of fiber glass reinforced plastics in rockets deduced from current information and advanced research studies were presented. The nose cone of the all-plastic missile would be quartz fiber reinforced phenolic which is forty times more efficient as a heat dissipator than the same weight of copper. The rocket case of filament-wound fiber glass epoxy is twice as efficient as the metal case of old-fashioned rockets. The exit nozzle of graphite cloth reinforced phenyl silane gives good stability and ablation resistance at 5000°F or higher. The rocket case liner for protection against the heat of combustion of polysulfide plastic-perchlorate fuel can be asbestos reinforced phenolic. External insulation of the rocket to extremes of tem-



IG. 3. Building epoxy-glass fiber cargo carrier. Step 3. Corrugated enter section of panel is placed in press. Outer skin is already in lace on under side. Similar skin will be applied to top surface and anel put under pressure for final curing.

perature is provided by rigid plastic foam covered with an erosion shield of Refrasil* reinforced modified phenolic.

The electronic guidance system would be potted in silicone rubber, and the payload will be placed in a compartment constructed of fiber glass honeycomb sandwich chosen for its low thermal conductivity and high strength-weight ratio.

Among the tables of properties presented by Raech to emphasize the utility of reinforced plastics were ones on thermal and strength/weight values for various metals and reinforced plastics.

*Refrasil is the vitreous silica fiber of H. I. Thompson Fiber Glass Co.

The specific conductivity, **1/kd**, where k is the conductivity and d the density, of fiber glass plastics is over 100 times greater than it is for metals like aluminum. The higher the value, the more efficient is the material as an insulator. Reinforced plastic is second to no metal on a specific strength basis, i.e., strength divided by weight. Values are 0.72 million inches for aluminum, 0.55 for magnesium, 0.69 for 4130 steel, 0.85 for fiber glass cloth epoxy, and 1.40 for fiber glass filament winding.

Polymers are being developed which have increasingly higher distortion temperatures. Improved epoxies now will withstand 550°F, and current research programs, largely based upon combining inorganic elements with resins, indicate possible products which will be stable as high as 900°F.

Technical Capabilities and Development in Engineered Missile Hardware.

By D. V. Rosato and J. J. Mobilia, Jr.,

Raytheon Company.

The performance of reinforced plastic materials in missiles, based upon requirements of high temperatures, structures, chemicals, ease of fabrication and other conditions, permits its use in many different parts. These include, beside the motor body, fins and nose cone, such parts as electrical connectors, internal insulation bulkheads, ducts, encapsulation of delicate equipment or instruments, specialty gaskets, etc. One of the more interesting aspects of reinforced plastics is that they can be infinitely modified to meet end use requirements. Design and application engineers can use reinforced plastics for fabricating parts which in some cases are impossible to produce out of metals.

(Continued in November)

FIG. 4. Building epoxy-glass fiber cargo carrier. Step 4. Floor and side panels are in position and roof panels are fitted to frame of cargo carrier.

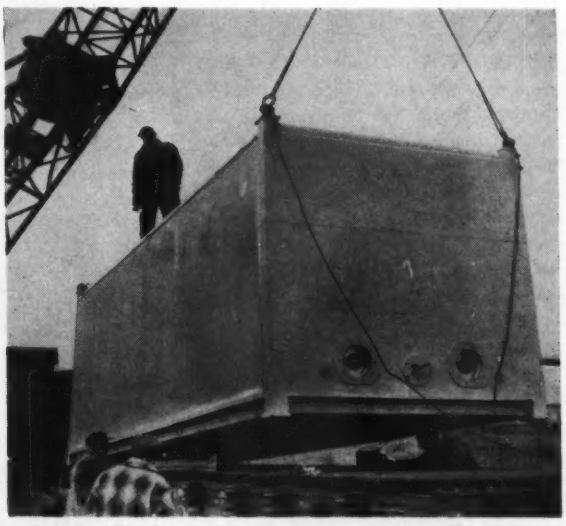


FIG. 5. Finished cargo carrier is loaded on railroad flat car. Construction allows carrier to be titled to 60-degree angle for easy discharge of of contents. Discharge spouts are visible in foreground.

• FIBER GLASS •

WILLIAM G. LANDRY is the new manager of the Corona, Calif., plant of Johns-Manville Fiber Glass Division. He succeeds Eugene Sinnett. Mr. Landry entered the field in 1955 when he joined Libbey-Owens-Ford Glass Fibers Company as chief industrial engineer. He continued in this position after the company was acquired by Johns-Manville in December, 1958.

William G. Landry

The Corona plant has been expanded to 196,200 sq. ft., which is nearly double its original size. The plant manufactures fiber glass thermal and acoustical insulation for the commercial, industrial and residential markets, including insulation for houses, mobile homes, aircraft, refrigerated truck-trailers, railroad cars, heating and air conditioning equipment, ducts and piping.

TYLER STEWART ROGERS retired from Owens-Corning Fiberglas Corporation to resume his former practice as consultant in the development, use and sales promotion of building materials.

Tyler S. Rogers

He has served as assistant to both the president and executive vice-president, manager of the Market Development and Design Division and as technical consultant. He also supervised the company's product and technical literature.

Mr. Rogers is a past president and director of The Producers' Council, Inc., former managing editor of American Architect and Architecture, and author of two books and numerous articles.

FIBER GLASS REINFORCEMENTS, INC., Los Angeles, has been appointed as a distributor for Johns-Manville fiber glass roving, chopped strands and *Garan Mat*. The materials are used extensively in fiber glass reinforced plastic manufacturing for such end products as aircraft parts, boats, translucent plastic panels, sports equipment, tote boxes, trays, housings and similar items.

The new distributor will also handle fiber glass cloth, another plastic reinforcing material. The company will cover all of California and Arizona. H. G. Hobbs, is president of the firm and John S. Frey is vice president.

H. G. Hobbs

J. S. Frey

A NEW ORGANIZATION has been formed in the fiber glass weaving field: Belding Corticelli Fiber Glass Fabrics, Inc. It is a composite of Carl Joseph Company, Inc., and Industrial Fiber Glass Fabrics, Inc., both of Kulpmont, Pa. The two companies were acquired by Belding Heminway Company, Inc., a producer of apparel fabrics and thread; under their new name they will weave decorative and industrial fabrics weave decorative and industrial fabrics.

FIBER GLASS MERGER. Fibre Glass Evercoat Corporation of Florida has been merged with a nationwide company bearing the same name. The national company manufactures fiber glass kits, glues, resins, epoxy coatings, automotive repair plastics, polyester and epoxy laminated products. Fibre Glass Evercoat of Florida sells most of its products to Miami boat builders.

The merger is expected to increase the national company's sales volume to over 5 million dollars.

A REINFORCED PLASTICS DESIGN AWARD for the most outstanding product at the Technical and Management Conference and Exhibition of the Reinforced Plastics Division, Society of the Plastics Industry, has been established by Owens-Corning Fiberglas Corporation.

Beginning with the 16th Annual Conference and Exhibition in Chicago next February the award, a modernistic crystal sculpture designed and made by Steuben Glass and titled "Counterpoise," will be presented annually by Owens-Corning to the company which manufactures the winning product.

A jury of experts in the design, engineering and editorial fields, appointed each year by the Society of the Plastics Industry, will determine the winning design. Factors in selecting the winner will be originality of application or design, material selection, color, utility, moldability and appearance.

APPLICATIONS

FIBER GLASS reinforced plastic materials help convert standard model automobiles to ambulances, funeral coaches, police patrol cars, and other special type vehicles. The Shop of Siebert, Waterville, O., an internation-

(Fig. A)

lly known builder of different types f coaches, has found it increasingly ostly to convert standard cars by using metal. Sheet metal components of the modern car body have become too complex, and hand working of metal is not economically feasible, since the company's yearly production is under

(Fig. B)

500. Cost of the necessary dies for metal work are estimated in excess of $250,000.

Now, through the use of fiber glass-plastic combinations, Siebert's indicated annual production of fiber glass molds can be carried out for a fraction of the sheet metal die cost.

As an example, the company uses Ford standard station wagons for con-

(Fig. C)

version into ambulances by removing the roof and cutting the side and quarter panels to allow for expansion and cutting away a section of the rear of vehicle for the rear door. Then, a wooden "buck" is constructed in the open areas (Fig. A) upon which is fashioned a clay model (Fig. B). A water-soluble parting agent of polyvinyl alcohol and wax is sprayed on the clay and epoxy resin and successive layers of fiber glass cloth and mat are laid up to form a mold of the desired thickness.

After a wooden frame is attached, the clay is removed and the mold is ready for use.

Components for the converted vehicle are made in the mold by laying up polyester resin, then, successively, three layers of 2-ounce mat and three layers of fiber glass cloth. The roof, side and quarter panel extensions, and the rear door, are made of fiber glass reinforced plastic (Fig. C).

Fiber Glass: Owens-Corning Fiberglas Corp., 717 Fifth Ave., New York 22, N.Y.
Research on fiber glass patterns and molds: Modern Pattern & Plastics, Inc., Toledo, O.
Automobile conversion: The Shop of Siebert, Waterville, O.

FIBER GLASS DUCTWORK is the solution to the unusual problems posed by sticky pigments at Eastman Kodak Company's largest manufacturing plant, the Kodak Park Works, Rochester, N. Y.

Formerly the exhaust system which carried off a sticky mixture of pigment, gelatin, formalin, dyes and water, was composed of metal ducts. However, the mixture not only adhered to the metal surfaces but hardened upon drying. Consequently the old system required a thorough weekly cleaning to remove the insoluble pigments, which caused high maintenance costs. Repeated cleaning, corrosion and usage finally resulted in the need for a new system. In evaluating materials to replace the metal ductwork the principal criteria were stringent physical requirements of the application including resistance to the corrosive effects of chemicals, cost, and ease of fabrication. Reinforced fiber glass was selected as the most practical and economical answer to the ductwork problem.

The new exhaust system of polyester reinforced fiber glass has virtually eliminated the cleaning and maintenance problem and the necessity of insulation to prevent "sweating." The system contains 11 hoods exhausted by 22 six-in. nominal diameter ducts. Each duct handles 500 cfm. of air and 2 gpm. of sprayed water and entrained chemicals.

Fiber glass reinforced polyester in ducts, trays, stacks, hoods, fans, tanks, trays, ejectors, hoppers, covers and allied units is proving a versatile means for cutting costs, improving productivity, increasing operating performance, and lengthening equipment serviceability in the chemical and other industries.

Fabricator, Fiber Glass Panels: Resolite Corp., Zelienople, Pa.
Fabricator, Fiber Glass Ductwork: du Verre, Inc., Arcade, N.Y.
Polyster Resin: Durez Plastics Division, Hooker Chemical Corp., Walck Rd., North Tonawanda, N.Y.

FIBER GLASS SKYLIGHTS, translucent and fire-resistant and developed to meet local industrial, institutional, school, commercial and residential building code requirements for flame-inhibiting skylights are said to remain unaffected by industrial fumes, salt water, and ordinary cleaning detergents.

The glass-cloth is reinforced with polyester and has a thermal conductivity equal to about 20 per cent of that of glass. Skylights transmit approximately 50 to 80 per cent of the light transmitted by glass and their brightness and illumination values are claimed to be in close agreement with those suggested by classroom lighting authorities. They are impervious to ordinary hailstorms, rocks, shock or vibration. Both single dome and double dome units are available in the following mounting types: rectangular, square, and round low self-flashing types; rectangular high self-flashing types; and square and round rectangular curb-mounting types. They are designed for roof openings ranging from 14″ x 14″ to 38″ x 74″.

Fabricator: Consolidated General Products, Inc. Consolite Division, 24th & Nicholson, P. O. Box 7425, Houston 8, Tex.
Polyester Resin: Durex Plastics Division, Hooker Chemical Co., Walck Rd., North Tonawanda, N. Y.

CAN YOU MAKE GLASS FURNACE HISTORY?

Chances are you can—in campaign duration and fuel economy—using Kaiser basic brick in the checkers.

These brick have consistently set new records. Recently an estimated **490 million cubic feet of gas was reported saved in a single campaign using Kaiser Periclase checkers.***

The principal reason: Kaiser Periclase brick are high in thermal efficiency... heat-up fast and release heat fast... maintain their efficiency over a long period of time. For example, a new and a used Periclase "D" brick (taken from top course of 18 month old checker) were tested for thermal efficiency:

	MEAN SPECIFIC HEAT		
	Specimen 1	Specimen 2	Specimen 3
NEW Periclase "D"	0.265	0.280	0.248
USED Periclase "D"	0.269	0.272	0.251

KAISER PERICLASE "D" (95% MgO) brick are particularly recommended for top courses in checker chambers. At service temperatures, Periclase "D" forms its ceramic bond of a tight network of pure periclase crystals—unifies the granular structure into a virtually impervious body which maintains a dry surface and superior resistance to erosion or buildup by carryover. Flues stay open. Furnaces stay on-line longer.

KAISER PERICLASE "A" (92% MgO) brick is used in the lower courses of the regenerator chamber because of their lower cost and high hot-load strength. For information about basic or fireclay refractories contact your Kaiser Refractories Sales Engineer or write to Kaiser Refractories & Chemicals Division, Kaiser Aluminum & Chemicals Sales, Inc. at any of the Division Offices listed below:

PITTSBURGH 22, PA. . . . . 3 Gateway Center
MEXICO, MISSOURI . . . . . Mex-R-Co Building
OAKLAND 12, CALIF. . . . . 300 Lakeside Drive

*Single 1773-day campaign of 284,036 tons used 1941 cu. ft. less gas per ton than previous 685-day campaign.

BASIC REFRACTORIES:

Kaiser Periclase "D" Brick burned and unburned
Kaiser Periclase "A" Brick burned and unburned
Kaiser Chrome Periclase Brick burned and unburned, plain and metal cased
Kaiser Periclase Chrome Brick burned and unburned, plain and metal cased
Kaiser Mortars for use with brick listed above

FIRE CLAY, SILICA and HIGH ALUMINA:

Jay Bee Maximul and **Rajah**—super-duty firebrick
Big Savage and **Morex**—high-duty firebrick
Alumex—50 to 90 per cent high alumina firebrick
Big 4 and **Viking**—intermediate-duty firebrick
Silica Firebrick—regular and super-duty
Insulating Materials—firebrick, block and castables
Refractory Castables—heavy and lightweight
Cements and **Mortars**—regular and super-duty

KAISER REFRACTORIES

NEWS
IN THE GLASS INDUSTRY
Personalities...

William F. Nelson

And Elmer L. Williams have joined the fundamental research staff, General Research Department, Owens-Illinois Glass Company. Dr. Nelson, a solid state physicist, will work in the field

William F. Nelson

of color centers in glasses and crystals and in the x-ray spectroscopy of solids. Dr. Williams, a physical chemist, will conduct diffusion studies in glasses by radio tracer and other methods.

Nelson served for the past seven years as head of materials research, Douglas Aircraft, Long Beach, California. Williams was a development engineer in semi-conductor diffusion studies, Sylvania Electric Products.

Stig B. Holmquist is now on the special projects section, General Research Department. He will work as a senior engineer with a group to de-

Elmer. L. Williams

velop new glass-crystalline materials. Formerly, he served with Harbison-Walker Refractories Company and U.S. Steel Corporation.

William L. Gumby

And I. Steinberg are now with the Organic Section of the Chemical Research and Development Laboratory, Bausch & Lomb Incorporated. . . . Paul D. Millin has joined the Laboratory's Electrochemical and Analytical Section.

R. H. Wecker

Assistant director, marketing research, Wyandotte Chemicals Corporation.

A. David Baumhart, Jr.

Assistant to the president, Libbey-Owens-Ford Glass Company. He is presently completing his third consecutive term in Congress as Representative from the 13th Ohio district.

Forrest F. Van Alstyne, boss cutter

A. David Baumhart, Jr.

in charge of sheet and window glass hand cutting, Shreveport, La. . . . W. Z. F. Walker transferred from Denver to Richmond as district sales manager.

William R. Daragan

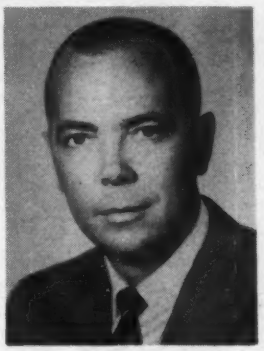
Technical service representative in New York, of Chlor-Alkali Division, Food Machinery and Chemical Corporation.

William G. MacNaughton

William G. MacNaughton, plant equipment sales representative, Eastern Sales District, Corning Glass Works. . . . Robert B. Gentles and William S. Brennan, sales engineers for electronic components. . . . Edward C. Kramer, Jr., senior sales engineer, Television bulb sales department.

William W. Young

Regional sales manager, American Potash & Chemical Corporation. He will open the company's first regional headquarters in Atlanta in the near future.



William W. Young

John R. Jones, New York-New England district sales manager. . . . William W. Kolyer, assistant district manager, Eastern market development office. . . . Harry L. Carroll, new sales representative, southern region.

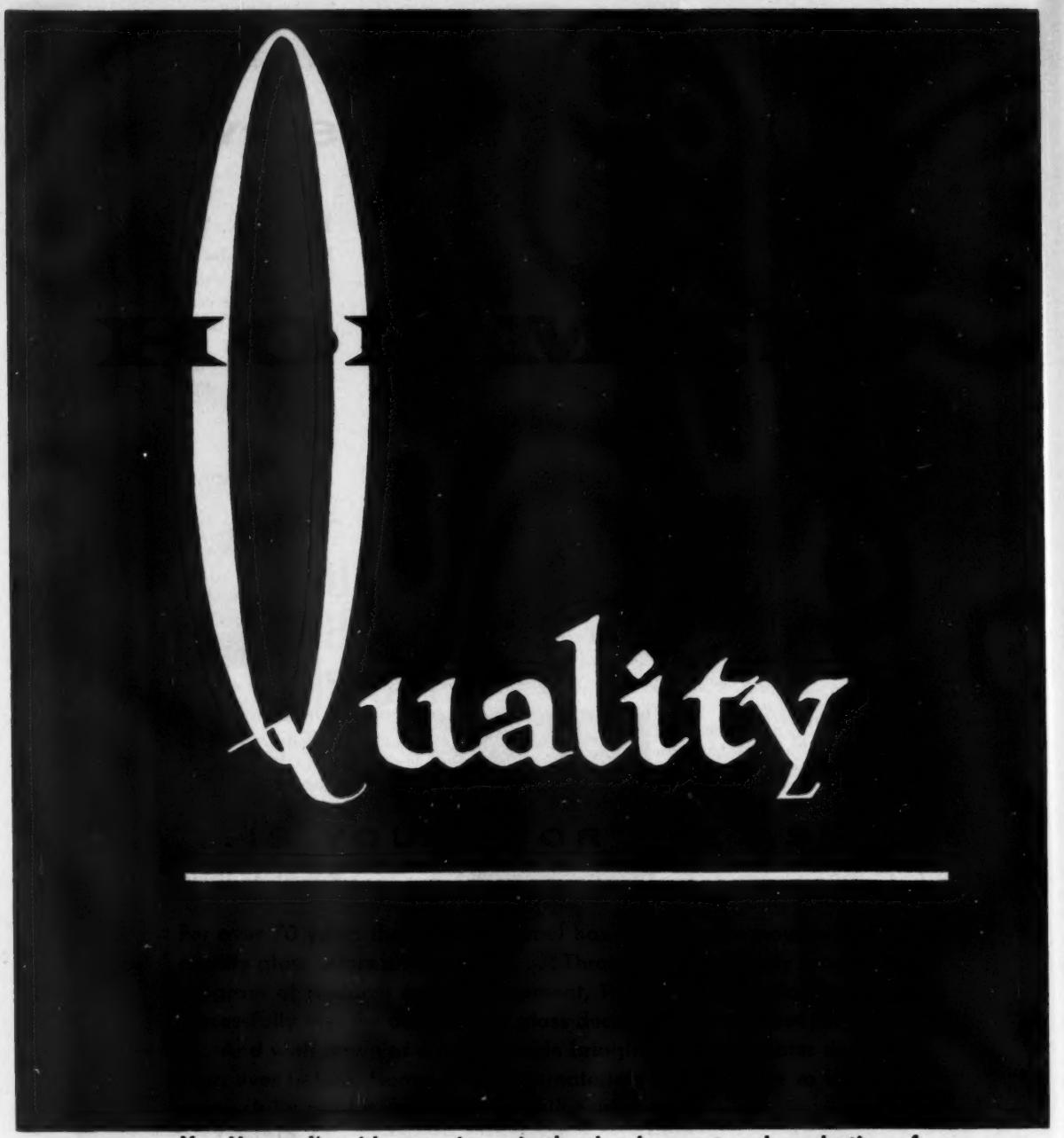
Robert A. Drake

Manager, Ball Brothers Company's new glass container manufacturing plant, Mundelein, Ill. Until 1955 he was with Olin Mathieson Chemical Corp.

C. G. Thrash, formerly manager of the Pittsburgh Sales Office, is now Chicago branch manager for the Com-

Robert A. Drake

mercial Container Division. S. E. Nielsen replaces him in Pittsburgh, and W. J. Hoshal succeeds Nielsen as a member of the Detroit sales staff.



Yes, Hommel's wide experience in the development and production of high quality glass colors is Yours for the Asking! . . . Talk to your Hommel representative . . . Or contact us direct.

THE O. HOMMEL CO.

PITTSBURGH 30, PA. Dept. GI-1060

HOMMEL

West Coast — 4747 E. 49th Street, Los Angeles, California

A. G. McNish

Chief, Metrology Division, National Bureau of Standards. This division has replaced the Optics and Metrology Division but contains all the sections of the old division plus the Mass and Scale Section and the Volumetry and Densimetry Section from the Mechanics Division.

Mr. McNish was formerly consultant to the Director and Acting Chief, Optics and Metrology Division.

As the new division is now constituted it will be in charge of establishment, maintenance, and dissemination of units and standards of length, mass, volume, light (including ultraviolet and infrared), and color; conducting research, devising test methods, and making calibrations to make these standards more available for Government and public use. It will also be in charge of determination of fundamental properties of materials such as refractive index and thermal expansion; calibration and testing of length standards and gages; measurement of optical apparatus and materials; photographic materials, reference weights, volumetric, density, and fluid capacity measures; development of new types of optical and photometric apparatus for military purposes; and furnishing consulting service to other Government agencies.

NBS has also established a new division, Instrumentation. G. Franklin Montgomery is chief. The old Electricity and Electronics Division is now the Electricity Division with Dr. C. H. Page as chief. The Mechanics Division has one new section, Pressure and Vacuum.

In the Heat Division, one section, Thermodynamics, has been disbanded, and four new sections have been established. The new sections and their chiefs are: Heat Measurement, Dr. D. C. Ginnings; Equation of State, Joseph Hilsenrath; Statistical Physics, Dr. M. S. Green; and Molecular Spectroscopy, Dr. D. E. Mann.

Richard F. Sperring

Assistant manager, Pittsburgh Plate Glass Company plant, Crystal City, Mo.

Kenneth Brierley

General manager, Industrial Products Group Division, Fall River, Mass., for Minneapolis-Honeywell Regulator Company. . . . Succeeded by John H. Hagen as head of the Rubicon Division.

A. G. McNish

Peter M. Button

Sales representative, Pittsburgh Corning Corporation, Kansas City.

Ted Rickets

On sales staff Falconer Plate Glass Corporation for upstate New York.

W. S. Till

Elected chairman of the New Jersey section, Illuminating Engineering Society. He is in charge of mercury-vapor-lamp commercial-engineering activities for Westinghouse Electric Corporation's Lamp Division, Bloomfield, N. J.

A member of the society for eight years, Mr. Till is currently serving on the industrial lighting and roadway lighting committees and has authored a number of technical papers which he has presented before regional and national conferences of the group.

Wendell T. Butler

Manager of the newly created market research division within the development department, Solvay Process Division, Allied Chemical Corporation.

W. M. Hampton, OBE

Retired as managing director, Chance Brothers Limited, Glassworks, Smethwick, England. Dr. Hampton served 43 years with the company. He joined the firm as a chemist and held the positions of manager of the Optical Glass Department, director of research, technical director and then managing director. He will remain a member of the Chance Brothers Board, vice-chairman of the Chance-Pilkington Optical Works Management Committee, and Chairman of the British Glass Industry Research Association.

C. J. S. Newman, a member of the board since 1951, succeeds Dr. Hampton as managing director.

J. H. Call

William T. Myers

Manager, production engineering, Hazel-Atlas Glass Division of Continental Can Company. . . . John H. Call manager, Hazel-Atlas plant in Zanesville, O.

H. Courtney Smith

Joined sales staff of the Glass Products Division, Fischer & Porter Company.

Glenn W. Jacobsen

Supervisor, Sales Engineering, Harbison-Carborundum Corporation.

Hyman B. Freehof

Examiner-in-Chief, U.S. Patent Office, U.S. Department of Commerce. He was appointed to the post by President Eisenhower on May 24 of this year.

B. M. Humphries

Presently assistant manager of sales development for the Beer and beverage industries, Armstrong Cork Company, is also manager of training. . . . William L. Martin, Jr., assistant manager, glass container sales administration, and assistant manager, sales development for the food industry. . . . George L. Goodhue, supervisor of the package design section. . . . J. R. Woods and Arthur S. Pfautz transferred to the Philadelphia district office.

Fellowship Established

A two-year post-doctoral fellowship, which provides $8,000 per year, has been awarded to Dr. Edgard Francis Bertaut, assistant professor of chemistry, Pennsylvania State University.

The fellowship has been established by Owens-Illinois Glass Company for study in the College of Mineral Industries at Penn State. Dr. Bertaut will study the chemistry and structure of glass surfaces under the direction of Professor W. A. Weyl.

Companies...

Glass Noise Suppressor

A thin, transparent panel of polyvinyl butyral plastic laminated between two layers of safety glass is proving to be an efficient sound controller. The plastic suppresses sounds at frequencies of 1,000 to 4,000 cycles per second, the range of many vocal and mechanical sounds.

Monsanto Chemical Company's Plastics Division produces the polyvinyl butyral plastic.

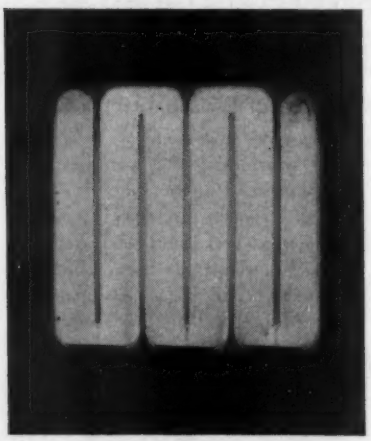
Ordinarily thin walls and windows transmit noises by vibrating in response to sound waves as though they were huge "speakers." In the acoustical laminated safety glass, however, the sound energy vibrations are dissipated by the molecules of the plastic interlayer and converted friction into tiny amounts of heat instead of passing through as noise.

New Fluorescent Light Source

A new fluorescent flat lamp—one and a half inches thick—consisting of a maze of passages sealed in a glass block through which the electric discharge travels, will soon be marketed by Westinghouse Electric Corporation's lamp division.

The device gives an area source of light rather than a line source produced by conventional tube-shape lamps, and the 12-inch square model of 40 to 50 watts will produce considerably more light than a 100-watt incandescent bulb.

The flat fluorescent lamp is expected to reduce maintenance costs sharply because it is necessary only to clean the outer glass surface. The labyrinth-type lamps can be installed in modular fashion, like glass brick or ceiling tiles.



PPG Moves Havana Office Operations

Pittsburgh Plate Glass International is moving its Havana, Cuba, office operations to San Juan, Puerto Rico. Dwight R. Means, president of PPGI, notified all employees of the Havana office that the move was approached with great reluctance but circumstances beyond his control made it necessary.

Space Research Contracts

Owens-Illinois Glass Company, Technical Center received two U.S. Air Force contracts from the Air Force Research Div., Air Research and Development Command, Wright-Patterson, O., for research on projects common to the space program. Contracts total $57,104.

The largest, worth $37,452, is the first government contract given to the company's Fundamental Research Department. Its subject is research in high temperature X-ray diffraction technology and the development of equipment to study crystal structure of materials at temperatures up to 3,000°F. The second contract is concerned with chemical analysis of silicon-boron mixtures, borosilicate glass, and zirconia-magnesia systems.

Volume Production—Resistors

Installation of new automatic machinery capable of producing huge quantities of resistors has enabled Corning Glass Works to push into the low-cost resistor market. The half-watt and one-watt sizes are manufactured by Corning Electronic Components, a department of Corning, and are already being supplied to the electronics industry for engineering evaluation. Peak production is expected to be reached in less than two months.

The market for these resistors totals an annual sales volume of approximately $50 million. Applications include electronic office machines, missile tracking systems, radio and television sets and electronic toys. These smaller size resistors are becoming increasingly important to meet the demand for miniaturized electronic equipment. Expanded laboratory facilities for ultrasonic delay line development at the Corning Electronic Components plant will more than triple developmental capability in the delay line field.

Mirror Manufacturing Plant

Binswanger Glass Company, which formally opened its enlarged and remodeled mirror manufacturing facilities at Grenada, Miss., in August, states that its $265,000 investment has greatly increased production capacity and quality control. Modern methods incorporated in the expansion include an Injectomatic system of spray silvering, galvanic method of electro-copper plating, completely automatic controls for infra-red baking and installation of an automatic stripping machine, and a face washing machine at the end of the conveyor. Diesel tractor trailer units owned by the company are used to ship mirrors to all U.S. markets.

$1 Million Missile Contract

International Resistance Company, Philadelphia, received a $1-million contract from the Autonetics Division of North American Aviation, Inc., to produce high stability, high reliability resistors for the Air Force's Minuteman ICBM.

The resistors are designed in the 25, 50 and 100 part per million per degree C temperature coefficient classes. They consist of an evaporated metal film type of completely inorganic design, hermetically sealed in glass with .145 diameter X.300 maximum length rated at one-eighth watt at 125°C. Their power rating is based on continuous full load operation at an ambient temperature of 125°C. For temperatures in excess of 125°C., the load is derated to zero at 165°C. Only one failure per one-quarter billion unit hours is permitted. This is a failure rate of one in every 65,000 units tested for 4,000 hours.

Falconer Plate Glass Corp.

Appointed Ace Glass Company, 567 Manor Blvd., San Leandro, Calif., as distributor of Falconer's mirror line in that area.

St. Joseph Lead Co.

Appointed the Great Lakes Foundry Sand Company, Ceramic Division, as a distributor for its lead-free zinc oxides. C. L. Cruikshank, manager of the Ceramic Division, will direct sales. Richard J. Marshall, will be responsible for sales in the Ohio, West Virginia and Pennsylvania areas.

Industrial Site

Owens-Illinois Glass Company purchased an 88-acre industrial site in Los Angeles for future use as the location of a manufacturing plant

Ball Bros. Inc.

Began constructing a glass container manufacturing plant at Mundelein, Ill. It is expected to be on stream by next spring. The company presently has glass manufacturing plants, in Muncie, Ind.; Hillsboro, Ill.; Okmulgee, Okla.; El Monte, Calif.; and Asheville, N.C.

U.S. Losing Domestic Sheet Glass Market . . .

According to Robinson F. Barker, vice president and general manager of the glass division, Pittsburgh Plate Glass Company.

Speaking before the United States Tariff Commission during several appearances, Barker said there is a "complete lack of justification for any further reduction in existing tariff duties," on sheet glass products.

He requested the Committee for Reciprocity to remove sheet glass from the list of products to be considered by the U.S. for any possible tariff reduction at the forthcoming GATT negotiations in Geneva, Switzerland.

The overwhelming cost advantages foreigners possess over domestic producers in wages and raw materials was cited as the most important reason for the success of foreign imports. The average hourly wages in Japan, excluding fringe benefits, were cited as 33¢ per hour in 1959. In West Germany and Belgium, including fringe benefits, such wages were 69¢ and 75¢, respectively. These were compared to PPG's hourly average of $3.72 for 1959.

Barker also pointed out that despite the cost advantages to foreign sheet glass competitors in wages, raw material, transportation and other costs, there has been a 65 per cent reduction of basic rates of duty on imported sheet glass in the U.S. since 1930. While U.S. tariff rates have dropped, foreign imports of sheet glass shot from 31,700,000 pounds in 1950 to 502,600,000 in 1959, a 1485 per cent increase.

The 1950 foreign sheet glass imports were equivalent to 2.5 per cent of the estimated domestic production, but by 1959 imports had increased to over 31 per cent of the estimated domestic production.

Pittsburgh Plate contends that "under these circumstances, no reasonable basis exists for consideration of any further reductions in our sheet glass tariff duties."

Glass Conference

The 21st Annual Conference on Glass Problems will be held at Ohio State University on Thursday and Friday, December 1st and 2nd.

ACS Pacific Coast Meeting

The 13th Pacific Coast Regional Meeting of the American Ceramic Society will be held at the Ambassador Hotel, Los Angeles, on October 19-20-21.

The program will open with a greeting from the Southern California Section, given by Chairman Myles P. Bennett, Gladding, McBean & Co., Los Angeles. ACS president George H. Spencer-Strong, Pemco Corporation, Baltimore, will welcome the guests on behalf of the American Ceramic Society.

Dean John F. McMahon, Alfred University, Alfred, N.Y., will speak on "Trends in Ceramic Education." The guest speaker for the opening luncheon will be Dr. Joseph Kaplan, Department of Physics, University of California, Los Angeles.

Among those papers, which will be delivered at the meeting, are the following:

GENERAL SESSION: Wednesday, October 19, 2:00 p.m. Symposium on Fuels.

Nuclear Fuels. Carl A. Trexel, Jr., senior industrial economist, Stanford Research Institute, Menlo Park, Calif.

Petroleum. Arthur C. Stewart, senior vice president, Union Oil Company of California, Los Angeles.

Coal. Carroll F. Hardy, associate director of marketing, National Coal Association, Washington, D.C.

Natural Gas for the Ceramic Industry. Charles T. Dierker, general staff supervisor, Industrial Sales, Southern California Edison Company, Los Angeles.

Electricity. Robert P. O'Brien, vice president, Southern California Edison Company, Los Angeles.

TECHNICAL SESSION: Thursday, October 20, 9:00 a.m. Special Ceramics, Electronics.

Crystallization Studies of Synthetic Mica. Albert Levine, General Telephone & Electronics Laboratory, Bayside, N.J.

New Designs of Ceramic Capacitors. Harold Reith, Packard Bell Electronics, West Los Angeles.

Recent Developments in High Purities and High Temperature Furnace Design. Michael A. Cocca, General Electric Research Center, Schenectady, N.Y.

TECHNICAL SESSION: Thursday, October 20, 9:00 a.m. Glass.

Easy Identification of Stones in Glass. David Johnson, Corhart Refractories Company, Inc., Louisville, Ky.

Furnace Design and Glass Melting. Roy S. Arrandale, Thatcher Glass Mfg., Co., Inc., Elmira, N.Y.

Fiber Glass and Its Uses. Leon E. McDuff, Johns-Manville Fiber Glass Inc., Corona, Calif.

TECHNICAL SESSION: Thursday, October 20, 9:00 a.m. Refractories.

Refractories of the Future. G. R. Eusner, United States Steel Corp., Applied Research Laboratory, Monroeville, Pa.

Extended Use of Laboratory Equipment to Evaluate Refractory Clays. R. R. Riley and L. S. Cook, research engineers, Gladding, McBean & Co., Pittsburgh, Calif.

Considerations for the Synthesis of Binary Spinels. F. A. Furguson and L. E. Marsh, Stanford Research Institute, Menlo Park, Calif.

GENERAL SESSION: Thursday, October 20, 2:00 p.m. Quality Control Symposium.

Process Control and Management Requirements. Frank N. Squires, Industrial Consultant, Los Angeles.

Production Requirements and Techniques of Quality Control. Glenn D. James, Los Angeles City College, Los Angeles.

Quality Control Demands of Consumers. Russell Chastain, buyer for glass and china, Broadway Department Store, Los Angeles.

TECHNICAL SESSION: Friday, October 21, 9:00 a.m. Glass.

Boric Acid, Lithium Compounds & Rare Earths in Glass. Dr. John L. Bills, American Potash & Chemical Corp., Los Angeles.

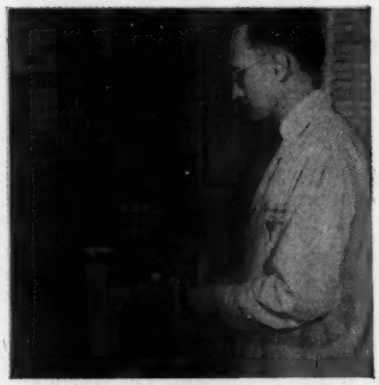
Air Systems—A New Development in Compression of Air in the Glass and Ceramic Industry. R. C. Coblentz, Air Systems Division, Lovell Mfg., Co., Erie, Pa.

HELPING HANDS ...for you!

You are in good hands when you call on Drakenfeld for help in solving color problems. Our technical staff in Washington, Pa., has a long history of successful color engineering for large and small companies at home and abroad.

Drakenfeld facilities include unique innovations in research devices and manufacturing methods. Many "firsts" in better colors and better color application saw the light of day in Drakenfeld laboratories.

The dependable color service Drakenfeld offers every customer is the result of a blend of long experience, varied technical skills, and strict production controls. We invite you to learn how well Drakenfeld can serve you in the wonderful world of color.



This color difference meter is one of several instruments we use to match colors for customers. For help on color problems, consider Drakenfeld a division of your company.

☆ ☆ ☆

DEPENDABLE SERVICE ON: Acid, Alkali, and Sulphide Resistant Glass Colors and Enamels... Crystal Ices... Porcelain Enamel Colors... Body, Slip, and Glaze Stains . . . Overglaze and Underglaze Colors . . . Squeegee and Printing Oils . . . Spraying and Banding Mediums . . . Metallic Oxides and Chemicals.

CALL ON *Drakenfeld*

OUR PARTNER IN SOLVING COLOR PROBLEMS

B. F. DRAKENFELD & CO., INC.

Executive Offices: **45 Park Place, New York 7, N. Y.**

Factory and Research Center: **Washington, Pa.**

Pacific Coast Agents:

BRAUN CHEMICAL COMPANY, 1363 So. Bonnie Beach Place LOS ANGELES 54, California Phone: ANgelus 9-9311

BRAUN-KNECHT-HEIMANN COMPANY, 1400 Sixteenth Street SAN FRANCISCO 19, California Phone: HEmlock 1-8800

INVENTIONS AND INVENTORS

Sheet and Plate Glass

Method of producing transparent electroconductive articles. Patent No. 2,894,858. Filed December 1, 1950. Issued July 14, 1959. No sheets of drawings; none reproduced. Assigned to Pittsburgh Plate Glass Company, by William O. Lytle.

In the production of articles which are the subject matter of this invention, a glass sheet, usually of plate glass or other flat glass structure (including bent or curved glass structures), is provided with conducting metal strips suitable for bus bars. It is the general practice to apply these bus bars to the base before the electroconductive oxide coating is applied; however, certain types of bus bars may be applied after the deposition of the electro-conductive film. The bus bars are generally located adjacent the edges of the glass (usually within .5 inch of the edge) and, in the preferred embodiments, are located on opposed marginal edges.

In practice it has been found that the most satisfactory compositions for use in preparing the bus bars comprise a highly conductive metal powder (preferably gold or silver) and a vitrifying binder. The ingredients forming the vitrifying binder, for example, lithrage, boric acid and silica, are heated to a sufficient temperature, for example 1700° F, to compel them to fuse and form a glass-like mass.

After application of the ceramic metal bus bars to the glass sheet by painting or other method, the sheet is heated to the temperature at which application of the conductive coating may be effected, for example, above about 400 to 800° F but below the fusion point of the glass, usually 950 to 1150° F. During this heating operation, the ceramic metal coating is fused onto the glass so that a firm bond is established between the glass and the metal coating.

When the glass has been heated for one or two minutes, it is withdrawn from the heating chamber and immediately is sprayed with the coating solution before substantial cooling of the glass sheet can take place. A quantity of the coating solution is placed in an atomizing spray gun and the heated glass sheet is sprayed with an atomized spray of this material for a brief period, usually of the order of 2 to 20 seconds, depending upon the thickness of film to be produced, the air pressure imposed upon the atomizing spray gun, etc. Usually this spraying operation is conducted in oxygen or air of atmospheric humidity.

This process results in the production of a base coated with a tin oxide electroconductive film.

Articles produced according to the above description, are suitable for use as viewing closures or windows. Usually they are laminated with a suitable plastic, such as polyvinyl butral, to reinforce the glass and provide a so called "safety glass" construction. The closures may be successfully heated by imposing an electric potential across the bus bars, thus using the conductive film as a resistance element.

There were 7 claims and the following references cited.

United States Patents

2,061,106, Schellenger, Nov. 17, 1936; 2,244,715, Long, June 10, 1941; 2,516,663, Zunick, July 25, 1950; 2,522,531, Mochel, Sept. 19, 1950; 2,537,671, Jack et al., Jan. 9, 1951.

Tube and Cane Machines

Glass for glow discharge lamps such as fluorescent luminescent lamps and the like. Patent No. 2,862,131. Filed March 15, 1954. Issued November 25, 1958. No sheets of drawings; none reproduced. Assigned to Societe Anonyme des Manufactures des Glaces et Produits Chimiques de St. Gobain, Cauny & Cirey by Jean Alfred Escher-Desrivieres.

It is an object of the invention to eliminate the harmful rays from the light emitted by glow discharge lamps without interrupting the other rays.

A composition of glass which was extensively employed during the experiments which culminated in this invention was as follows:

	Per cent
SiO_2	70.62
Al_2O_3	0.71
Fe_2O_3	0.07
CaO	5.33
BaO	1.97
MgO	3.49
Na_2O	16.52
K_2O	1.01

This glass is transparent to practically the whole spectrum down to about 2,890 A., for the thicknesses which are generally used in making the walls of glow discharge lamps. It was an attainment of this invention to eliminate from transmission through such glasses the wave band between 2,890 A. and 3,200 A. without affecting the transmission of light of visible wave lengths.

A glass provided with the desired characteristics may be produced by introducing up to 1 or preferably .5 per cent in weight of vanadium oxide or cerium oxide or a mixture of these oxides into the glass composition. As about a half weight per cent or less of the oxides is effective, it is not ordinarily useful to add more, but there is some minor variation in the percentage which produces the optimum effect with a particular glass.

There were 14 claims and the following references cited.

United States Patents

1,726,635, Taylor, Sept. 3, 1929; 2,413,940, Bickford, Jan. 7, 1947; 2,581,440, Pincus, Jan. 8, 1952; 2,582,453, Pincus, Jan. 15, 1952; and 2,599,349, Ricker, June 3, 1952.

CURRENT STATISTICAL POSITION OF GLASS

Employment in the glass industry during June, 1960, was as follows: *Flat Glass:* a preliminary figure of 25,500 for June, 1960, indicates a decrease of 4.1 per cent under the adjusted figure of 26,600 reported for May, 1960. *Glass and Glassware, Pressed and Blown:* an increase of 2.6 percent is shown by the preliminary figure of 92,900 reported for June, 1960, when compared with the adjusted figure of 90,500 reported for May, 1960. *Glass Products Made of Purchased Glass:* the preliminary figure of 13,600 given for June, 1960, is 0.7 per cent under the adjusted figure of 13,700 reported for May, 1960.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers

	July, 1960
Food	1,322,000
Medicinal and Health Supplies	1,135,000
Chemical, Household and Industrial	846,000
Toiletries and Cosmetics	906,000
Beverage, Returnable	998,000†
Beverage, Non-returnable	174,000
Beer, Returnable	239,000††
Beer, Non-returnable	1,561,000
Liquor	693,000
Wine	300,000
Sub-total (Narrow)	8,174,000

† The figure reported for June (1,280,000) has been revised to to 1,443,000 gross. (See page 518, September issue.)

†† The figure reported for June (664,000) has been revised to 501,000 gross. (See page 518, September issue.) Sub-total remains 9,369,000 gross.

Wide Mouth Containers

Food	*3,610,000
Medicinal and Health Supplies	343,000
Chemical, Household and Industrial	159,000
Toiletries and Cosmetics	210,000
Dairy Products	130,000
Sub-total (Wide)	*4,452,000
Total Domestic	12,626,000
Export Shipments	136,000
TOTAL SHIPMENTS	*12,762,000

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production July 1960	Stocks July 1960
Food, Medicinal and Health Supplies; Chemical, Household and Industrial; Toiletries and Cosmetics	Narrow Neck	4,997,000	8,148,000
	Wide Mouth	*4,738,000	*7,281,000
Beverage, Returnable		**984,000	2,241,000
Beverage, Non-returnable		204,000	338,000
Beer, Returnable		**280,000	469,000
Beer, Non-returnable		1,707,000	948,000
Liquor		784,000	1,485,000
Wine		363,000	783,000
Dairy Products		128,000	368,000
TOTAL		*14,185,000	*22,061,000

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

** Figures reported for June (see page 518, September issue) have been revised. Beverage, Returnable (1,102,000 gross) is now 1,212,000 gross. Beer, Returnable (686,000 gross) is now 576,000 gross. Production total remains 14,806,000 gross.

Payrolls in the glass industry during June, 1960, were as follows: *Flat Glass:* a decrease of 4.4 per cent is shown in the preliminary $13,767,240.90 given for June, 1960, when compared with May's $14,403,767.27. *Glass and Glassware, Pressed and Blown:* an increase of 2.1 per cent is shown in the preliminary $37,286,881.89 given for June, 1960, when compared with the previous month's adjusted $36,527,514.98. *Glass Products Made of Purchased Glass:* a preliminary figure of $4,332,445.38 was reported for June, 1960. This is an increase of 0.6 per cent when compared with the adjusted figure of $4,329,555.27 for May, 1960.

Glass Container Production based on figures released by the Bureau of the Census, Industry Division, was 14,185,000 gross during July, 1960. This is a decrease of 4.1 per cent under the previous month's production figure, 14,806,000 gross. During July, 1959, glass container production was 13,811,000 gross, or 2.6 per cent under the July, 1960, figure. At the end of the first seven months of 1960, glass container manufacturers have produced a preliminary total of 94,792,000 gross. This is 5.2 per cent more than the 90,038,000 gross produced during the same period in 1959.

Glass Container Shipments during July, 1960, came to 12,762,000 gross, a decrease of 10.8 per cent under June, 1960, which totaled 14,313,000 gross. Shipments during July, 1959, amounted to 13,385,000 gross, or 4.8 per cent more than July, 1960. At the end of the first seven months of 1960, shipments have reached a preliminary total of 89,763,000 gross, which is 2.4 per cent more than the 87,590,000 gross shipped during the same period of the previous year.

Stocks on hand at the end of July, 1960, came to 22,061,000 gross. This is 6.6 per cent more than the 20,681,000 gross on hand at the end of June, 1960, and 17.0 per cent more than the 18,852,000 gross on hand at the end of July, 1959.

WHERE ACCURACY PAYS OFF IN PROFITS FOR YOU!

Pinpoint accuracy in preparing the batch, exact blending of components, excellent adherence to dimensions of the finished product—together they contribute to the performance characteristics of FC-101, Fusion Cast Refractory, noted for extreme purity, higher refractoriness, superior surface texture and resistance to thermal shock. This proven quality in combination with proper fit, imparted by dimensional accuracy, results in easier, faster installation, longer service life and greater all-around satisfaction to the user. Add to this the years of painstaking research that has paid off for you—and us—through the perfection of several "firsts" in glass refractories and you have the reasons why FC-101 and other Walsh products for the glass industry have set the new quality standard. Wire, write or phone for details.

WALSH REFRACTORIES CORPORATION

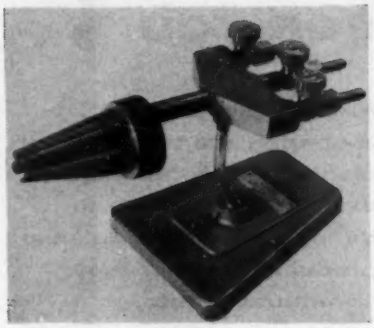
America's Best Clays

WALSH REFRACTORIES CORPORATION

101 FERRY STREET • ST. LOUIS 7, MISSOURI

FOR OVER 60 YEARS THE GLASS INDUSTRY'S PARTNER IN PROGRESS

NEW EQUIPMENT AND SUPPLIES



Lab Burner

Provides a variety of distinct flames through 5 tapered tips, ranging from tiny, sharp needle, to bushy tongue. Pre-mixed gas and oxygen produce a hot, sharply pointed flame with temperatures from 2000° to 3000°C. Tips are attached to a rotating turret and flame passes directly from the ignited burner tip to the succeeding tip, eliminating re-ignition of the flame each time tips are changed. Knurled, rotating turret is said to remain cool. Stability is accomplished by a broad heavy cast-iron base. Burner is secured to the base by a ball and socket mount for adjustability. It is less than 8" high.

Fisher Scientific Co., 498 Fisher Bldg., Pittsburgh 19, Pa.

Wet Scrubber

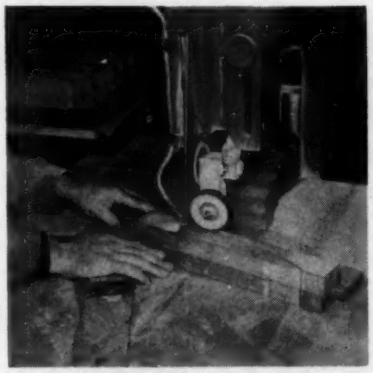
Developed to handle dust, fume or odor problems in ceramics, chemical, pharmaceutical, food processing, and other industries. Pilot unit tests have shown efficiencies up to 99 per cent on materials as fine as fly ash. Scrubbing is achieved by vortexing the gas flow in a series of chambers. Each chamber is shaped to produce a swirling action within the chamber so that the gas is scrubbed with water. The wetted dust particles are centrifuged out of the gas stream. The gas flows through ventrui-shaped throats for increased velocity to impinge wetted dust particles against the wall and obtain more violent vortexing, for a more positive scrubbing.

Available in capacities from 1,000 cfm to 60,000 cfm the units are compact; 1,000 cfm model is only five feet high including the moisture extractor on top, and the 10,000 cfm unit is 5′ x 5′ x 19′ high. Models from 1,000 cfm to 10,000 cfm have the following standard equipment: reservoir, liquid level control, moisture extractor, and one or more water-tight access doors. A setting pond is required for heavy dust loading and high temperatures.

The Johnson-March Corp., Philadelphia, Pa.

Diamond-Coated Band Saws

Cut pattern shapes in glass-reinforced plastics, glass, ceramics, marble and



other hard materials. Saw widths range from diamond-coated wire to 1¾" bands. Fiber glass laminates can be cut without a coolant, but heavy material such as thick glass needs water or water-and-oil coolant. Both edge-coated and fully coated bands are available.

Dia-Chrome Co., Glendale, Calif.

Vibratory Feeders

Features a rated output of 75 tons per hour when operating level. There is a substantial increase when the machine is operated downslope. An electro-permanent magnetic drive system is operated directly from alternating current and needs no rectifier. Drive elements are completely enclosed, protected against damage or decreased efficiency due to contamination by moisture and foreign materials. Unit is available with five standard size trays in flat and tubular designs.

Eriez Mfg., Co., Erie 6, Pa.

Insulating Windows

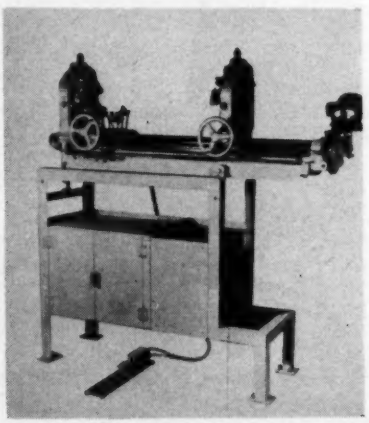
Available in 36 standard sizes ranging in width from 20" to 40 7/16" and in height from 16" to 24 7/16". Air space thickness between panes is approximately 3/16".

Libbey-Owens-Ford Glass Co., Toledo, Ohio.

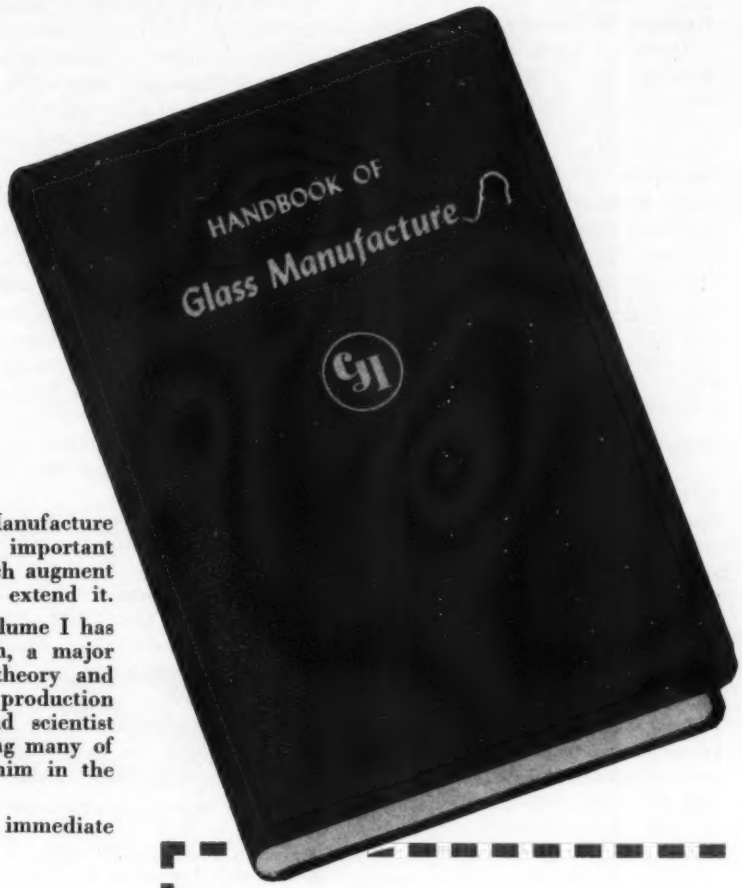
Glassworking Lathe

Said to meet a broad range of requirements including the fabricating of ring seals, tees, flanges, glass fusings, closures, and a variety of repairs. It can be changed from horizontal to upright position in two minutes or less. Bed table pivots for the change, eliminating need for separate, vertical table. Change to vertical is claimed to permit greater control of glass flow for glass-to-metal seals, long tapers on tubing, and other operations. Tailstock lock mechanism permits use of chuck as a rigid vise and headstock rotates for operations such as flaring. Maximum chuck capacity is 8". Through-spindle diameter is 4". Total weight of lathe is 198 lbs.

Bethlehem Apparatus Co., Hellertown, Pa.



IT'S HERE!
VOL. II
HANDBOOK
OF GLASS MANUFACTURE



Volume II of the Handbook of Glass Manufacture deals with a number of significant and important topics in the glass industry, some of which augment the subject matter in Volume I, others extend it.

The basic purpose and philosophy of Volume I has been preserved in Volume II and, again, a major concept is to bridge the gap between theory and practice . . . and to provide for the production executive, the engineer, technologist and scientist an effective starting point for approaching many of the practical problems which confront him in the course of his work.

Order your copy of Volume II now for immediate delivery.

CONTENTS . . .

OPTICAL PROPERTIES
N. J. Kreidl, *Bausch & Lomb Incorporated*

EFFECTS OF HIGH ENERGY RADIATION
N. J. Kreidl, *Bausch & Lomb Incorporated*

CHEMICAL ANALYSIS OF GLASS
Francis W. Glaze, Consultant (A-D)
John Tims, *Owens-Corning Fiberglas Corp.* (E)

THE QUALITY CONTROL CHART
Ronald Wiley*, *Owens-Corning Fiberglas Corp.*

SCIENTIFIC GLASSBLOWING: GLASS FABRICATION
Vincent DeMaria, *Glass Products Development Laboratory*

GLASS COMPOSITION, DEVITRIFICATION AND STRUCTURE
Fay V. Tooley, *University of Illinois*

FLAT GLASS MANUFACTURING PROCESSES
Roy G. Ehman, *Pennsylvania State University*

ELECTRIC MELTING OF GLASS
Larry Penberthy, *Penberthy Electromelt Co.*

*Now with Deering Milliken Research Corp.

Ogden Publishing Company
55 West 42nd Street, New York 36, New York

Date.....

Enclosed please find remittance in the amount of $..... to cover the cost of ..... copy(ies) of Volume II of the HANDBOOK OF GLASS MANUFACTURE. Single copy price, $10.00. Order for 5 or more copies, 10% discount. Add Shipping and Insurance charges, domestic 60¢ per copy; foreign 90¢ per copy. Foreign remittance in U.S. dollars.

NAME .....

COMPANY .....

STREET..... CITY..... STATE.....

Glass-Ceramic Cement

To seal glasses and other materials with thermal expansion between 80 and 92 x 10^{-7} cm/cm/°C. Cement fires at approximately 450°C and the resulting seal is serviceable up to about 425°C. Substance is said to match very closely the expansion of glasses used in industrial and military cathode ray bulbs. Available in one and five-pound kits, including powder and vehicle.

Industrial Bulb Dept., Corning Glass Works, Corning, N.Y.

Pneumatic Conveyor

Versatile two-way (pressure-vacuum) pneumatic conveying system for handling dry, free-flowing solid materials. Designed to lift materials by vacuum or pressure for either loading or unloading or to convey materials long distances in horizontal or vertical movement. Can be used with flexible tube or fixed pipe (or in combination); to convey materials through buildings, across tracks or to load and/or unload overhead, flat and hard-to-reach storage, processing and shipping facilities. Electric or internal combustion power is optional.

Daffin Mfg. Co., Lancaster, Pa.

Greaseless Vacuum Joint

Glass joint developed for laboratory use provides a greaseless, vacuum-tight seal engineered for high-temperature atmospheric and vacuum distillation applications and infrared and mass spectrometer analysis. Joint is available in four sizes and consists of two glass arms with spherical ends. Each expanded spherical end has a precision groove for seating an O-ring of corrosion-resistant rubber. Joint is available in four sizes with arm ID diameters of 7, 16, 20 and 40 mm.

Corning Glass Works, Corning, N.Y.

Acoustical Glass

Cellular-glass sound conditioning material for use in the long-accepted but seldom utilized concept of distributed or "patch" absorption where sound absorbing material is scattered in "patches" around various surfaces. The cellular-glass acoustical units measure 13½" x 13½" x 2½" with four, square 2½" x ½" thick pads on the back for mounting, thus furnishing ½" air space behind each unit. Air space results in maximum absorption efficiency together with valuable diffusion effects. Each unit of integral, non-fibrous material is independent. The units are spaced according to needs and intended use of the room, not butted together like tile. The inorganic glass units are said to be incombustible, rigid, strong and dimensionally stable. They may be mounted mechanically or with adhesives.

Pittsburgh Corning Corp., 1 Gateway Center, Pittsburgh 22, Pa.

Gas Detector Tape

A flexible adhesive-backed tape bearing indicators which turn a stated contrasting color on exposure to a specific gas or liquid. Can detect leakage of as little as 1/100 cc per hour of anhydrous ammonia, chlorine, hydrogen, hydraulic fluids per MIL-H-5606, acid fumes and other gases and fluids common to missile, aircraft and general industrial fields.

Pyrodyne, Inc., 11973 San Vicente Blvd., Los Angeles 49, Calif.

Heat-Resistant Gloves

Gloves with leather palms and aluminized asbestos backs and thumbs, designed to reflect 90 per cent of all radiant heat where high temperature work is involved. Suitable for furnace work, and welding and cutting operations. Available in five-finger carpincho leather glove; one-finger mitten; and five-finger glove.

Air Reduction Sales Co., 150 E. 42nd St., New York 17, N.Y.

Nepheline Syenite

New, improved Grade A-30 nepheline syenite for glass making. Fines are removed giving a more ganular product. Material is said to minimize segregation problems and give better batching efficiency. Dust loss is decreased in loading; handling to and from storages; and in batch mixing and changing.

American Nepheline Corp., 4720 Kenny Rd., Columbus 21, Ohio

CATALOGS RECEIVED

Silicones. (16 pages) Summary of forms, properties and applications of silicones. The silicone products reviewed range from adhesives to release agents, laminating resins to rubber compounds, and electrical insulation to water repellents. Photographs, tables and graphs.

DOW CORNING CORP., Midland, Mich.

Rare earths, thorium, chemicals. (8 pages) Complete technical information about various chemicals, metals and alloys of the rare earth group of elements; thorium, scandium and yttrium. Describes manufacture and lists detailed properties and chemical analysis of more than 50 products.

VITRO CHEMICAL CO., 261 Madison Ave., New York 16, N.Y.

Molybdenum products. (24 pages) Nontechnical, descriptive booklet containing full details on various sizes, forms, conditions of use, tolerances, weights and methods of identifying molybdenum products.

CLIMAX MOLYBDENUM CO., Division, American Metal Climax, Inc. 1270 Avenue of the Americas, New York 20, N.Y.

Refractories. (2 pages) Description of the various brands of fireclay brick with illustrations of the modern equipment used in manufacturing. Property descriptions are given on leading medium, high and superduty fireclay refractories used in glass and steel furnaces, ceramic cement and lime kilns and petroleum refining and petrochemical furnace equipment.

HARBISON-WALKER REFRACTORIES CO., Pittsburgh 22, Pa.

Feeders and rotary valves. (7 pages) Describes and illustrates with photos, charts and diagrams the complete line of roll and vane-type feeders and rotary valves. Equipment is designed to handle a large variety of dry, pulverized and granular materials, including chemicals, clay and mineral products, and powdered metals.

FULLER CO., Catasauqua, Pa.

Thermocouple components. (28 pages) Contains specifications and ordering information on replaceable components for thermocouple assemblies. Components covered are bare elements, elements with insulators, insulators, metal and ceramic protecting tubes, heads, blocks, connectors and miscellaneous fittings.

MINNEAPOLIS-HONEYWELL REGULATOR CO., Wayne and Windrim Aves., Philadelphia 44, Pa.

Fused quartz glass. Detailed technical description of the optical properties of various grades of fused quartz glass. Graphs and tables compare transmission, absorption, dispersion and refractive indices of the quartz types for a wide range of wavelengths and in various thicknesses.

ENGELHARD INDUSTRIES, Inc., Technical Information Dept., 75 Austin St., Newark 2, N.J.

GAS COMPONENTS IN GLASS

(*Continued from page* 556)

stopcock leading to the pump is then closed. A blank test is then carried out for 1½ hours with the same procedure as in the gas analysis to be explained later. If the result of this blank test is less than about 1 per cent of the quantity of gas to be extracted, a lump of the sample is dropped into the platinum furnace while maintaining temperature. This is done by moving the metal piece by means of a magnet outside the tube. When the sample stops boiling, another piece is pushed in.

Gas Analysis

The gases pumped with the Toepler pump *T-1* from the extracting apparatus are condensed in the trap *F-1*, which is cooled with liquid oxygen. The stopcock *1* is closed after 1½ hours. If the trap is kept at certain low temperatures, different gases evolve at different temperatures.

Generally it is understood that the dissolved gases in glass are CO_2, SO_2 H_2O, O_2, CO, H_2, N_2, mainly CO_2, SO_2, H_2O. At the boiling point of liquid oxygen (−183°C.) the vapor pressures of H_2, N_2, O_2, and CO are high, and those of CO_2, SO_2, and H_2O are very low. At this point the gases having high vapor pressures evolve as non condensing gases. As shown in Fig. 5, the lower part of a copper tube is cooled with liquid oxygen. By controlling the height of this Cu tube, it is possible to raise the temperature of the trap by suitable steps.

Around −140°C. most of the CO_2 evaporates, but SO_2 and H_2O remain because of their low vapor pressures. At −73°C., obtained by alcohol and dry ice cooling, SO_2 evaporates, but not H_2O. Finally, the trap is immersed in warm water (35°C.), and H_2O evaporates. The relation between the temperatures and the vapor pressures thus obtained is plotted in Fig. 6. With the known capacity of the analytical apparatus, the volume of gas evaporated at each step can be calculated.

In case non-condensable gases are present, the oxygen is measured by determining the decrease in pressure when the gas is passed over hot copper in the tube *H-1* in Fig. 3. CO and H_2 are determined similarly by passing over hot CuO and freezing out the products of oxidation. However, the amount of non condensable gas components was relatively small in the glass which was studied and the separation of these gases was felt unnecessary.

It is known that the microanalysis of gas based on low temperature separation is highly accurate. In order to overcome the effects of the vapor pressure of the grease used for a vacuum seal, the gas on the wall of the glass apparatus, and the temperature changes, the

THE GLASS INDUSTRY

For 1959

BOUND VOLUMES for the year 1959 (with index) still available

$11.00 ea. domestic and foreign

BOUND VOLUMES for the year 1958 (with index) are available in limited quantity only

$11.00 ea. domestic and foreign

THE GLASS INDUSTRY
55 W. 42 St., N.Y. 36, N.Y.

Please send me:

☐ One copy of THE GLASS INDUSTRY 1959 BOUND Volume.

☐ One copy of THE GLASS INDUSTRY 1958 BOUND Volume.

Name _____

Company _____

Address _____

☐ Bill me ☐ Check enclosed*

* Postage and handling: add 75c domestic; $1.25 foreign.

analysis was carried out with a vacuum of 10^{-3} mm. Hg. The error is within 1 per cent. The effect of volatile constituents in the glass samples used for this experiment could be ignored.

In the following analysis the amount of gas is expressed in cc. at standard conditions per lg. of the sample.

Evolving Process of Dissolved Gas

According to the reports[17, 18, 19] on optical glasses, a large amount of gas dissolved in glass is observed. The amount of dissolved gas and its composition in glass of the Na_2O-CaO-MgO-SiO_2 system is not clear. The sample used for this experiment belongs to the Na_2O-CaO-MgO-SiO_2 system. The process by which the gas is evolved, in particular the relationship between the temperature of extraction and the amount of gas evolved, is studied. Also, changes in the amount of the gas at a constant temperature with time are studied in this experiment. The composition of the sample is in Table I.

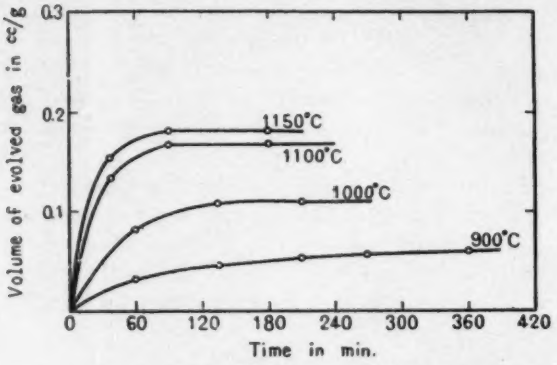


FIG. 9. Amounts of $CO_2 + SO_2$ evolved vs. time.

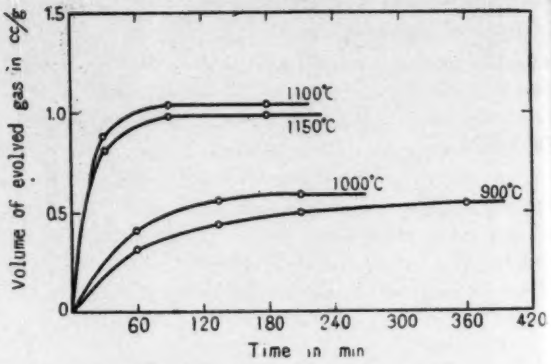


FIG. 10. Amount of H_2O evolved vs. time.

Table I

SiO_2	71.8%	MgO	3.9%
Al_2O_3	1.6%	K_2O	0.2%
Fe_2O_3	0.1%	Na_2O	13.8%
TiO_2	0.3%	SO_3	0.3%
CaO	7.8%	Ignition loss	0.3%

The relation between the temperatures of extraction and the amount of evolved gas is shown in Fig. 7. At

TECO

IN THE GLASS
CENTER OF THE WORLD

Offering a complete service to all branches of the Glass Industry

- Glass Melting Furnaces
- Fuel Oil Systems
- "Air-Clad" Gas Burners
- "Univerbel" Batch Charger
- "Austel-Escher" Recuperators and Firing Systems
- Annealing and Decorating Lehrs
- "Hydrostatic" Bottle Testers

ENGINEERS – DESIGNERS – CONTRACTORS

TOLEDO ENGINEERING Company INC.

3003 Sylvania Ave., Toledo 13, Ohio
GReenwood 5-1529

900°C. the sample heated for 6 hours still evolves small amounts of gas, but when heated to 1000°C. for 3 hours, it stops evolving gas. At 1100° and 1150°C. all of the dissolved gas was evolved within 2 hours. The sample evidently contained limited amounts of dissolved gas because it stopped evolving gas even though it was heated for 1 more hour. The amounts of gas evolved at 1200°C. and 1150°C. were almost the same.

The total volume of evolved gas and the volume of each separate component at N.T.P. with the extracting temperatures, are shown in Table II and Fig. 8. The volume of evolved gas increased as the temperature increased, but above 1100°C. no increase was noticed. In consequence, evolution of dissolved gas in glass is a sort of equilibrium phenomenon. From the fact that Na_2CO_3 and Na_2SO_4 almost decompose in vacuum at 1000°C. or 1100°C., and the consideration that there is a relationship between the components of alkali and the amount of dissolved gas in glass, it is believed that the gas is not merely dissolved physically but that the molecules of the gas are combined chemically in the structure of glass and are evolved by reheating to the extracting temperature.

Table II

Temp (°C)	Total volume of evolved gas (cc/g)	Volume of separated gas (cc/g) CO_2+SO_2	H_2O	Non-cond. gas
900	0.127	0.065	0.058	0.005
1000	0.191	0.111	0.062	0.018
1100	0.266	0.165	0.101	trace
1150	0.275	0.180	0.095	trace

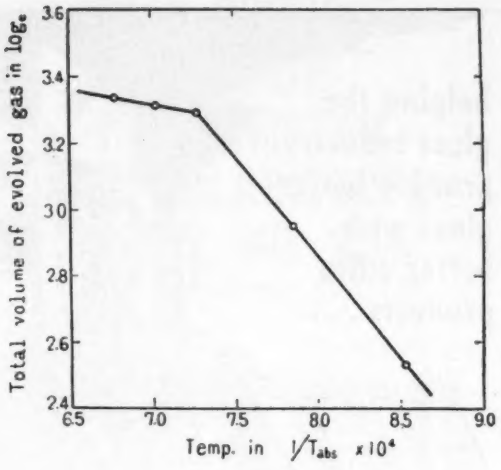


FIGURE 11

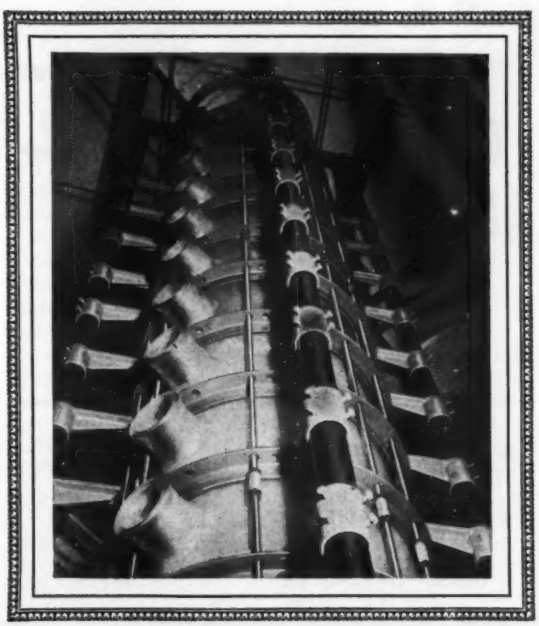
As shown in Fig. 7, the speed of extraction of gas sharply increases as the temperature rises. Some gas still evolved slowly at 900°C. even after 6 hours of evolution, but at 1000°C. it stops within about 2 hours. Moreover, at 1100°C. about 90 per cent of the dissolved gas in glass evolves within 30 minutes, and the evolution

How well do you know your glass?

HERE YOU SEE:

- ☐ 1. Carboys
- ☐ 2. TV tower
- ☐ 3. Distillation column
- ☐ 4. Telescope

Standing 16 feet tall and weighing almost a ton, this all-glass bubble cap distillation column was constructed by Corning Glass Works for use in the manufacture of metallic silicon. In 70 years as supplier of Soda Ash to the glass industry, Wyandotte has witnessed many remarkable industrial applications of glass. Today, as in the past, Wyandotte is a working partner supplying technical assistance and raw-material chemicals to those great companies marking milestones in glass progress.



Wyandotte CHEMICALS

Michigan Alkali Division, Wyandotte Chemicals Corporation
Wyandotte, Michigan • Offices in principal cities

Founded by a Glassmaker to Serve the Glass Industry

helping the glass industry produce better glass with better silica products . . .

OTTAWA

SILICA SANDS

THE WORLD'S FINEST SILICA SAND

99.9% PURE

Headquarters for highest purity and greatest uniformity in Silica.

OTTAWA SILICA COMPANY
Plants Located In Ottawa, Ill., Rockwood, Mich., Connecticut & California

SERVING THE FOUNDRY, GLASS AND CERAMIC INDUSTRIES FOR OVER 50 YEARS

Designed Specifically for GLASS!

WESTCOTT

Glassworking CHUCKS

Originally developed for use in manufacturing TV tubes, this self-centering Handwheel Actuated Chuck has proved its value on many other operations handled on glassworking lathes where ACCURACY, SIMPLICITY, and SPEED of operation are essential.

- **FAST OPERATION** Handwheel control. No wrench required.
- **LARGE CAPACITY** Outrigger type jaws.
- **ADAPTABLE TO ANY GLASSWORKING LATHE**

Send for FREE Circular

Users of WESTCOTT GLASSWORKING CHUCKS include:
- CORNING GLASS WORKS
- WESTINGHOUSE
- GENERAL ELECTRIC
- CALIFORNIA RESEARCH CORPORATION
- SYLVANIA ELECTRIC
- MACHLETT LABORATORIES

ONEIDA MACHINE TOOL CORPORATION
2000 E. WALNUT ST. ONEIDA, N. Y.
Manufacturers of Westcott Chucks and Glass Manufacturing Equipment

ends after 1½ hours. As shown in Figs. 9 and 10, each component of the gas behaves like the total volume. At 1150°C., heating for 1½ hours, the amounts of CO_2 and SO_2 evolved are 0.151 cc/g and 0.029 cc/g.

Evolution and absorption of gas are considered as reversible phenomena for metal, but it is doubtful whether the same holds true for glass. According to the research on optical glass[21] done by T. T. Neuman, most of the gas is dissolved around 1150°C. Also, this author feels that evolution and absorption of gas in glass is almost similar to the reversible phenomenon, as in metal. G. Borelius noted that for the absorption of gas in metal, the amount increases with temperature increase. He set up the following relationship between the amount of absorption S and temperature T[22].

$$S = Ce^{-\frac{E_s}{2RT}}$$

C = constant, Es = heat of fusion, and log S and I/T show the straight line relation. He stated that at points of discontinuity deformation of the metal or change or combination of internal gas occurs. The result of this research, which studied gases in glass, as shown in Fig. 12, shows that the straight line is bent. Also, it shows that gas in glass exhibits the same sort of equilibrium phenomena as in metal. It is thought that it is possibly a reversible reaction.

Conclusion

A considerable amount of gas is dissolved in glass. This gas has a large effect on the character of the glass. In order to understand the state of absorpotion of the gas, it is necessary to study the phenomena of its evolution.

The authors studied the amounts of the components of gas in glass and their rate of evolution. Up to the present, the results of analysis in the extraction of gas in glass have been inaccurate. This has been due to the difficulties in sealing the tubes and then cooling, since the glass samples must be heated at high temperature in a high evacuated vessel. The very great care that must be taken with the apparatus also presents a problem.

For these experiments, the authors set up apparatus which improves upon earlier methods. With this apparatus experiments were carried out on the way in which gas is evolved from glass in the soda-lime-magnesia system. The relationships between the extraction temperature and the volume of gas evolved and the velocity of evolution were particularly studied. The general results were that when extracting at a constant temperature, the volume of gas evolved increased with time until it reached a constant limit. With rising extraction temperature, the velocity of evolution and the volume of gas evolved increased, but above 1150°C. there was hardly any further increase.

The volume of gas evolved was 0.275 cc/g (N.T.P.)

and the composition was CO_2 55 per cent; SO_2, 10 per cent; H_2O, 35 per cent; non-condensed gas, trace.

With this apparatus the absorption of gas in molten glass may be investigated. By studying how the components of a gas mixture are absorbed by glass as well as the influence of this gas on the properties of the glass, the phenomena associated with the melting and refining of glass, and the structure of glass itself, may also be studied. Thus, it will be valuable for learning more about the nature of glass.

BIBLIOGRAPHY

1. M. A. Besborodov, A. A. Sokolova and G. A. Shinke, J. Soc. Glass Technol., *19*, 143 (1935).
2. H. Jebsen-Marwedel, Glastechnische Fabrikationsfehler 58-99 (1936).
3. J. Lofier, Glastech. Ber., *23*, 11 (1950).
4. A. E. Badger, Ceram. Ind., *27*, 17 (1936).
5. W. A. Weyl and A. P. Pincus, Glass Ind., *19*, 255, 347, 417, 455 (1938).
6. E. M. Firth, F. W. Hodkin, M. Parkin and W. E. S. Turner, J. Soc. Glass Technol., *10*, 129 (1926).
7. A. E. J. Vickers, J. Soc. Chem. Ind. (London), *57*, 14 (1938).
8. Ikutaro Sawai, Ikuzo Kubo, Bull. Inst. Chem. Research, Kyoto Univ., *9*, 127 (1939).
9. J. Boow and W. E. S. Turner, J. Soc. Glass Technol., *22*, 357 (1938).
10. R. H. Dalton, J. Am. Ceram. Soc., *16*, 425 (1933). J. Am. Chem. Soc., *57*, 2150 (1935).
11. R. Bunsen, Ann. Physik. Chem., *20*, 545 (1883); *22*, 145 (1884).
12. R. G. Sherwood, J. Am. Chem. Soc., *40*, 1645 (1918).
13. J. E. Harris and E. E. Shumacher, Ind. Eng. Chem., *15*, 174 (1923).
14. R. I. Razouk and A. S. Salem, J. Phys. & Colloid Chem., *52*, 1208 (1948).
15. E. T. Allen and E. G. Zies, J. Am. Ceram. Soc., *1*, 739 (1918).
16. E. W. Washburn, F. F. Footitt and E. N. Bunting, Univ. of Ill. Eng. Expt. Sta. Bull., No. 118 (1920).
17. H. Salmang and A. Becker, Glastech. Ber., *5*, 520 (1928); *6*, 625 (1929); *7*, 241 (1930).
18. C. Hahner, G. Q. Voigt and A. N. Finn, J. Research Nat. Bur. Standards, *19*, 95 (1937).
19. H. A. Shadduck and A. V. Zee, J. Am. Ceram. Soc., *25*, 69 (1942).
20. J. J. S. Sebastian and H. C. Howard, Ind. Eng. Chem., Anal. Ed, *6*, 172 (1934); N. R. Champbell, Proc. Phys. Soc. (London) *33*, 287 (1921).
21. T. T. Neuman, Glastech. Ber., *21*, 175 (1943).
22. G. Borelius, Ann. Physik, *83*, 121 (1927).

DANISH GLASSWARE

(*Continued from page* 561)

England and Scotland, and is represented at several Danish museums; also at the Victoria & Albert Museum in London, and at the Corning Glass Museum, Corning, New York.

Jacob E. Bang has been art consultant at Kastrup Glasvaerk since 1955 and was one of the founders of the Permanent Exhibition of Arts and Crafts, 1931. Among the most recent awards he has received are the bronze medal, 1954, and silver medal, 1957, at the Triennale in Milan.

One of the most prominent art consultants for Kastrup is Sigvard Bernadotte, son of King Gustaf Adolph VI of Sweden.

Holmegaards Glasvaerk, the first glass factory in Denmark, was founded in 1825, about 50 miles from Copenhagen. The first glassmakers came from Norway and Bohemia and were later supplemented by Danish glassmen who were taught the trade. Initial production was largely household glassware, including bottles and jars. These were described as "solidly technical in quality, and in the rather heavy Empire style of the time."

Holmegaards art glassware and service glasses today are exported to about 77 countries, the United States and England being among the most important buyers.

Kastrup Glasvaerk, established in 1847, employs 1100 persons in three factories. The company exports glass-

DUAL PURPOSE POLAROID* POLARIMETER AND POLARISCOPE MODEL NO. 204

A.S.T.M. designation #C 148-59T

Horizontal and Vertical Views

Analyzer is mounted within calibrated circle reading clockwise from 0° to 180° and counter-clockwise from 0° to 180°.

For use as a polariscope, the analyzer is set to read zero. The polarizing field is a typical red-purple and strain is seen in characteristic colors for tension and compression.

* T.M. Reg. U.S. Pat. Off. by Polaroid Corp.

Polarizing field 10" diameter.
Binocular analyzer. The shaded eyepiece makes the use of the instrument practical on the open floor with regular shop illumination.
Distance between analyzer and polarizer 16".
For use as a polarimeter, the sensitive tint plates are swung out of the optical path by a finger movement; this movement automatically brings the quarter wave plates into the optical path. The polarizer now appears as a typical dark extinction field and a strained glass specimen is seen as a shaded black to white area. To measure this strain, the calibrated analyzer is rotated until the light area turns to maximum darkness. The reading of the calibrated circle, in degrees, multiplied by 3 (or more precisely 3.03) is equal to the retardation in millimicrons, of that strained area. The instrument may be used in any position from the vertical to the horizontal.

THE POLARIZING INSTRUMENT COMPANY, INC.
IRVINGTON-ON-HUDSON, NEW YORK